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Highlights

A Loan Waiver Needed

Economic Valuation of Parthenium

Mixtures on Weed Dynamics

Effect of Post Emergence Herbicides

Discovering Thoughts, Inventing Future

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Effect of Post Emergence Herbicides and their Mixtures on Weed Dynamics, Yield Components and Yield of Rice (*Oryza Sativa* L.), At Guraferda Woreda, South Western Ethiopia

By Getachew Mekonnen, Mitiku Woldesenbet & Wubishet Alemu
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Abstract- Weeds are the principal limiting biological factor in national rice production, with losses that vary from region to region, depending on the cultivation system, predominant weed communities and weed control methods employed by the farmers. Therefore, the experiment was conducted in Bench Maji Zone at Guraferda Woreda, during the 2017 main cropping season to investigate the effect of Bispyribac-sodium 10% SC, and 2, 4-D amine salt on weeds growth, yield components and yield of rice and to investigate the possibilities of supplementing low doses of herbicides with hand weeding for effective and cost effective weed management. There were 12 treatments comprising: Bispyribac-sodium 10% SC (20 g ha-1 ,25 g ha-1,30 g ha-1), 2, 4-D amine salt (0.75 L ha-1,1.0 L ha-1 , 1.25 L ha-1), Bispyribacsodium 10% SC 20 g + 2, 4-D amine salt 0.75 L ha-1, Bispyribac-sodium 10% SC 10 g + 2, 4-D amine salt 1.0 L ha- 1, Bispyribac-sodium (20 g ha-1) + hand weeding and hoeing at 35DAE , 2, 4-D amine salt (0.75 L ha-1) + hand weeding and hoeing at 35DAE, Weed free and Weedy checks. The design of the experiment was RCBD with three replications. The majority of the weeds in the experimental fields were broadleaved, grassy and sedges.

Keywords: *broadleaved and grass weeds, economic analyses, bispyribac-sodium, 2, 4-d amine salt, yield loss.*

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Effect of Post Emergence Herbicides and their Mixtures on Weed Dynamics, Yield Components and Yield of Rice (*Oryza Sativa* L.), At Guraferda Woreda, South Western Ethiopia

Getachew Mekonnen [α], Mitiku Woldesenbet [σ] & Wubishet Alemu [ρ]

Abstract- Weeds are the principal limiting biological factor in national rice production, with losses that vary from region to region, depending on the cultivation system, predominant weed communities and weed control methods employed by the farmers. Therefore, the experiment was conducted in Bench Maji Zone at Guraferda Woreda, during the 2017 main cropping season to investigate the effect of Bispyribac-sodium 10% SC, and 2, 4-D amine salt on weeds growth, yield components and yield of rice and to investigate the possibilities of supplementing low doses of herbicides with hand weeding for effective and cost effective weed management. There were 12 treatments comprising: Bispyribac-sodium 10% SC (20 g ha^{-1} ,25 g ha^{-1},30 g ha^{-1}), 2, 4-D amine salt (0.75 L ha^{-1},1.0 L ha^{-1} , 1.25 L ha^{-1}), Bispyribac-sodium 10% SC 20 g + 2, 4-D amine salt 0.75 L ha^{-1}, Bispyribac-sodium 10% SC 10 g + 2, 4-D amine salt 1.0 L ha^{-1}, Bispyribac-sodium (20 g ha^{-1}) + hand weeding and hoeing at 35DAE , 2, 4-D amine salt (0.75 L ha^{-1}) + hand weeding and hoeing at 35DAE, Weed free and Weedy checks. The design of the experiment was RCBD with three replications. The majority of the weeds in the experimental fields were broadleaved, grassy and sedges. The influence of herbicides on weed density, weed dry biomass, weed control efficiency and weed index were clearly noticeable at harvest. The uppermost weed control efficiency 86.7% was noted from 2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE which was in parity with Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE. Bispyribac-sodium 10% SC 25 g ha^{-1} was effective in reducing weed index (18.77%). Suggestively lower number of tiller per plant, panicle length per plant and thousand seed weight was recorded with weedy check. The weed free check treatment recorded 43.76% higher yield over weedy check. Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE gave the highest harvest index (45.13%). The highest yield loss 62.44% was recorded in weedy check. The maximum net benefits were acquired with the application of Bispyribac-sodium 10% SC 25 g ha^{-1}, followed by 2, 4-D amine salt 1.0 L kg ha^{-1}. If low-cost and plenty labour are available Bispyribac-sodium 10% SC 20 g ha^{-1} + hand weeding and hoeing at 35 DAE should be done. With the availability of herbicides, Bispyribac-sodium 10% SC 25 g ha^{-1} followed by 2, 4-D amine salt 1.0 L kg ha^{-1} can be used to prevent the yield loss and to obtain maximum benefits from rice.

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Keywords: broadleaved and grass weeds, economic analyses, bispyribac-sodium, 2, 4-d amine salt, yield loss.

I. Introduction

Rice (*Oryza sativa* L.), is the staple food of over half world's population and in Asia 1.3 billion and four hundreds of millions of people in Africa and Latin America depend on it for their diet [1]. Out of 472.39 million tonnes of Rice production in the world, 85 per cent is used for human consumption. Globally rice is cultivated in an area of 157.8 million hectare with a production of 491.3 million tonnes (2016-2017) [1]. Rice is a recent crop introduced to the Ethiopian farming systems and the cultivation of the crop has begun at Amara Region and Gambella plains in the early 1970's [2]; [3]; [4]. It is considered to be a highly productive crop next to maize in the country [5] and is an important market oriented crop. The introduction and expansion of rice production in suitable agro ecologies, therefore, could be an option to achieve food security and self-sufficiency. The country has immense potentials for growing the crop. According to ministry of agriculture and rural development report [6], the potential area for rice production in Ethiopia is estimated to be about thirty million hectares. Cereals specifically rice the one in which, the government has also recognized it as a millennium crop in light of ensuring food security in Ethiopia. It has also given especial focus to Agriculture in the poverty reduction strategy [7].

However weeds grow profusely in the rice fields and reduce crop yields drastically. Nowadays, weeds are considered as major biological constraints that reduces the potentiality of rice [8]; [9]. The risk due to weeds is lower in rice since the age old plants are transplanted so that the competition from the weeds is lower [10]. De to weed competition during the crop production the decrease in the yield was estimated to about 16 - 86 % [11].

Among different weed management methods, hand weeding is labourious, costlier and time consuming. Hand weeding is the predominant weed control practice on smallholder farms [12]. This method

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had been the oldest method of weed control which consists of hand pulling, hand slashing and hoeing of weeds. It is the major weed control method used in cereals production, but it is labor intensive and slow as compared to other manual weeding operations. It is usually delayed until the weeds are tall enough to be firmly held in the hand [13]. Smallholder farmers spend 50-70% of their total labour time in hand weeding [14]. On top of this, 69% of farmers' children between the ages of 5-14 are forced to leave school and are involved in the agricultural sector, especially at peak period of weeding [15].

Chemical control is a better alternative mechanism to manual weeding because it is cheaper, faster and gives better weed control [14]. The inability to control weeds by hand, lack of labour, and the drudgery involved in weeding in wet and or dry conditions will encourage and increasingly justify the use of herbicides [16]. Herbicide use would also improve the lives of farmers as it is devoid of farmer's engagement in such tedious task which may result in lifelong back deformities. By reducing the labour requirement for weed control, herbicide use could allow additional resources to be invested in food crops to the benefit of food security [17]. Studies showed that herbicides resulted in 97% greater wheat yield in comparison to the farmer practice of one hand weeding in Ethiopia [18]. Chemical control gave 38-55% higher crop yields, and had a 28-50% lower cost than farmer control methods [14].

As described above, weeds can be controlled by different methods. Even though, there exist different mechanisms of weed management, they vary in their efficiency of controlling weeds. Therefore, research has to be conducted to increase the efficiency of these methods and to decrease their hazardous effects. Now a day, there is large scale expansion of crops production in Ethiopia. This necessitates the use of herbicide due to shortage of labour and high labour cost during the peak periods.

Integrating herbicides with other weed management methods is an option for better weed control. IWM does not preclude herbicide use, it includes their judicious use along with other agronomic methods that help crops to compete with weeds and reduce weed seed production. IWM involves using an agronomical approach to minimize the overall impact of weeds and, indeed, maximize the benefits. The use of a single herbicide may result in shifting the weed flora in favor of the species that are not controlled, thus may increase the problem in the future. Therefore, herbicide combination is applied to broaden the spectrum of weeds controlled and sometimes the combinations can give spectacularly good control at doses considerably below those normally applied in single application. It may be additive or synergistic or prevent rapid detoxification of herbicide and are safer to crops and the user [14].

Consequently, information on herbicidal weed management practices in rice is limited in Southern Ethiopia in general and in Bench Maji Zone in particular. Therefore, the research was conducted to develop efficient, economical and herbicidal weed management practices for rice. The specific objectives were:

- To find out the effect of Bispyribac-sodium 10% SC, and 2, 4-D amine salt on weeds, and growth, yield components and yield of rice.
- To investigate the possibilities of supplementing low doses of herbicides with hand weeding for effective weed control.

II. Materials and Methods

a) *Description of Study Area*

The experiment was conducted in Southern Nations Nationalities Peoples Region, Ethiopia during the 2017 main cropping *'Meher'* season, in Bench Maji Zone at *Guraferda Woreda* research site.

b) *Experimental Materials*

New Rice for Africa (NERICA- 4) was used for this experiment. The key features of the new varieties, panicle can hold up to 400 grains compared to the 75-100 grains of its African parents, with an increase in yield from 1 to 2.5 t/ha which can increase to 5 t/ha with fertilizer use. It also matures 30-50 days earlier than traditional varieties. The adoption and cultivation of new rice varieties are increasing faster than any other food crops in many African countries [19].

Table 1: Description of herbicides used in the experiment

	Common name	Trade name	Chemical name
1	2,4-D Amine Salt	Power 860 SL	2,4-Dichlorophenoxyacetic acid
2	Bispyribac-sodium 10% SC	Pride 100 SC	Sodium 2,6-bis[(4,6-dimethoxy-2-pyrimidinyl)oxy]benzoate

c) *Treatments and Experimental Design*

The experiment was consisting of 12 treatments:

T1= Bispyribac-sodium 10% SC (20 g ha^{-1}) (Postemergence)

T2= Bispyribac-sodium 10% SC (25 g ha^{-1}) (Postemergence)

T3= Bispyribac-sodium 10% SC (30 g ha^{-1}) (Postemergence)

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T4= 2, 4-D amine salt (0.75 L ha^{-1}) (Postemergence)
T5= 2, 4-D amine salt (1.0 L kg ha^{-1}) (Postemergence)
T6= 2, 4-D amine salt (1.25 L ha^{-1}) (Postemergence)
T7= Bispyribac-sodium 10% SC 20 g + 2, 4-D amine salt 0.75 L ha^{-1} (Postemergence)
T8= Bispyribac-sodium 10% SC 10 g + 2, 4-D amine salt 1.0 L ha^{-1} (Postemergence)
T9= Bispyribac-sodium (20 g ha^{-1}) + hand weeding and hoeing at four- five weeks after crop emergence
T10= 2, 4-D amine salt (0.75 L ha^{-1}) + hand weeding and hoeing at four- five weeks after crop emergence
T11= Weed free check
T12= Weedy check

The design of the experiment was randomized complete block design (RCBD) with three replications. The plot sizes were 3 m X 2.4m. The distance between adjacent replication and plots were 1 and 0.5 meter respectively. The plot is consisting of 12 rows and 16 plants per rows spacing of 25cm x 15cm. The outer most two rows from each side of a plot and two plants on both ends of each row were considered as border and not be included for recording the observations. Thus, the net plot sizes were 2 m x 1.8m (3.6m^2).

d) Experimental Procedure

The experimental field was prepared following the conventional tillage practice before sowing the crop. In accordance with the specifications of the design, a field layout was prepared. The sizes of each experimental plot were 3 m x 2.4 m (7.2 m^2). The blocks were separated by 1m wide open spaces and the plots within a block were 0.5m apart from each other. Next to lay out the plots were leveled manually. Each treatment was assigned randomly to the experimental plots within a block. The rice NERICA-4 variety, it were planted on June 30/06/ 2017 with a spacing of 25 cm between rows and 15 cm between plants. There were 12 rows in each plot and 16 plants in each row. The herbicides were applied as the treatment in the assigned plots post emergence at tillering stage of rice. The amount of herbicides as per the treatment was calculated and measured using sensitive digital balance and measuring cylinder. Herbicide spray volume with water as carrier were 400-500 l /ha. Spraying was done with manually operated Knapsack sprayer (15 L capacity) using flat-fan nozzle. The spraying was done using a Knapsack sprayer. Hand weeding (hand weeding and hoeing) were done in the assigned plots as per the treatment. Harvesting was done, when the panicle and leaves were turned yellow. The harvested produce was sun dried for 3-5 days. Threshing and winnowing were done simultaneously and manually.

e) Data to be collected

i. *Data collection on weeds*

Data on weed flora present in the experimental field were recorded during the experimental period.

Weed Density: The weed populations were counted just at the time of first weeding, about 15 days before the expected harvest time. The population count (broadleaved, grass and sedges) were taken with the help of 0.25 m x 0.25 m quadrate thrown randomly at two places in each plot and were converted to category wise population/density per m^2.

Dry weight: While recording weed population the aboveground biomass will also be harvested from each quadrate. The harvested weeds were placed into paper bags separately and sun dried before drying in oven at a 65^{0}C temperature till constant weight subsequently the dry weight were measured.

Parameters for Weed Control

Weed Index: It will be measured from a particular treatment when compared with a weed –free treatment and will be expressed as percentage of yield potential under weed free.

$$\text{Weed Index} = \frac{x-y}{x} X\ 100$$

Where X= Yield from weed free; Y= Yield from a particular treatment

Weed Control Efficiency (WCE) - It were calculated from weed control treatments in controlling weeds.

$$\text{WCE} = \frac{(WDC-WDT)X}{WDC} 100$$

Where WDC=weed dry matter in control; WDT= weed dry matter in treatment

ii. *Data collection on crop*

Days to heading: It was recorded when the ears or panicles were fully visible on 50% of the plants from each plot by visual observation.

Plant height (cm): It was determined from measurements of 10 randomly pre-tagged mother shoots from ground level to the top of the spike excluding the awns at physiological maturity.

Number of panicles per plant: Number of panicles per plant were counted from the pre-tagged 10 plants at physiological maturity and the average were recorded as number of panicles per plant of m^{-2}.

Days to maturity: Days to maturity were measured as the number of days from emergency to the day when 85% of the plants reached physiological maturity, i.e. both panicles and plants turning yellow (senescing) based on visual observation.

Thousand grain weight: Thousand grains were counted in each plot using electronic seed counter from a bulk of threshed grain and their weight were measured using a sensitive balance at harvest and the weight were adjusted to 12% moisture content.

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*Total Dry Biomass (kg ha $^{-1}$):*Total dry biomass yield including straw and panicles of plants in a net plot area were measured using spring balance after sun drying to a constant weight.

Harvesting index (%): It were calculated as the ratio of grain yield to biological yield and expressed in percentage.

$$\mathbf{HI}(\%) = \frac{\mathbf{Grain\ Yield}}{\mathbf{Biological\ Yield}} * \mathbf{100}$$

yield loss (YL): Percent relative yield loss were calculated as the difference of grain yield from weed free yield and weedy yield and expressed in percentage.

$$\boldsymbol{RYL} = \frac{\boldsymbol{WFY - WY}}{\boldsymbol{WFY}} * \mathbf{100};$$ Where,

YL= Yield Loss, WFY=Weed Free Yield, WY=Weedy Yield

f) Data Analysis

Data were analyzed following a procedure appropriate to the design of the experiment [20] using appropriate statistical software. The treatment means that were significantly different at 5% levels of significance were separated using the LSD test.

III. Result And Discussion

a) Weed Parameters

i. *Weed Community*

The major weeds in the experimental fields were broadleaved, grassy and sedges. Fifty four weed species found infesting the experimental fields belonged to nineteen families. The major weed families competing vigorously with rice were Poaceae (12) and Asteraceae (10) and Chenopodiaceae (4). The current weed flora recorded was in accordance with the previous studies. They reported that there were as many as 350 species of more than 150 genera of 60 plant families were considered weeds of rice. Out of these, weeds of poaceae family ranked first that include more than 80 weeds [21].

Table 2: Weed community recorded in rice field at the experimental sites in 2017 cropping season

Weed species	Families	Life form
Abyssinian grass	Poaceae	Grass
Agerantum conyzoides	Asteraceae	Herb
Amaranthus graecizans L.	Amaranthaceae	A herb
Amaranthus hybridus L.	Amaranthaceae	Herb
Amharanthus spinosus L.	Amaranthaceae	Herb
Argemone mexicana L	Papaveraceae	Herb
Avena fatua L.	Poaceae	A grass
Avena vaviloviana	Poaceae	Grass
Bidens pilosa	Asteraceae	Herb
Chenopodium fasciculosum	Chenopodiaceae	Herb
Chenopodium oplifolium	Chenopodiaceae	Herb
Chenopodium opulifolium Schr.	Chenopodiaceae	A herb
Chenopodium procerum	Chenopodiaceae	Herb
Commelina benghalensis L.	Commelinaceae	Herb
Commelina latifolia A. Rich	Commelinaceae	P herb
Coreopsis borianiana	Asteraceae	Herb
Cuscuta spp	Convolvulaceae	Parasite
Cynodon dactylon (L.) Pers.	Poaceae	P grass
Cynodon nlemfuensis	Poaceae	Grass
Cynoglossum lanceolatum Forssk	Boraginaceae	Herb
Cyperus assimilis Steud	Cyperaceae	Sedge
Cyperus esculantus L.	Cyperaceae	Sedge
Cyperus rotundus L.	Cyperaceae	Sedge
Datura stramonium L.	Solanaceae	A herb
Digitaria abyssinica	Poaceae	Grass
Eleusine indica (L.) Gaertn	Poaceae	Grass

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Eragrostis cilianensis (All.) Vign. Ex Janchen	Poaceae	A grass
Galinsoga parviflora Cav	Asteraceae	Herb
Galium hamatum L.	Rubiaceae	A herb
Guzotia scabra (Vis.) Chiov.	Asteraceae	A herb
Heliotropium cinerascens Steud. ex DC.	Boraginaceae	Herb
Lantana camara L.	Verbenaceae	Shrub
Launaea cornuta	Asteraceae	Herb
Lolium temulentum L.	Poaceae	Grass
Mimosa invisa	Fabaceae	Herb
Nicandra physalodes	Solanaceae	Herb
***Oldenlandia herbacea* L.**	Rubiaceae	Herb
Orobanche ramosa L	Orobanchaceae	Herb
Oxalis corniculata L	Oxalidaceae	Herb
Oxygonum sinuatum (Meissn.) Dammer	Polygonaceae	A herb
Parthenium hysterophorus L.	Asteraceae	A herb
Phalaris paradoxa L.	Poaceae	Grass
Polygonum nepalense Meisn	Polygonaceae	Herb
Rumex abyssinicus Jacq.	Polygonaceae	Herb
*Senna didymobotrya (*Fresen.)	Fabaceae	Herb
Setaria verticillata (L.) Beauv.	Poaceae	A grass
Snowdenia polystachya (Fresen.) Pilg.	Poaceae	A grass
Solanum nigrum L.	Solanaceae	A herb
Stellaria media L.	Caryophyllaceae	Annual
Tagetes minuta L.	Asteraceae	Herb
Tapinanthus globiferus	Loranthaceae	Annual
Tribulus terrestris L.	Zygophyllaceae	A herb
Xanthium spinosum L.	Asteraceae	A herb
Xanthium strumarium	Asteraceae	Herb

ii. *Weed density*

Effect of herbicides on weed density was clearly visible at harvest. Weed density differed significantly due to herbicidal weed management practices at harvest. Among all the treatments, the weed free treatment and weedy check plots exhibited lowest and highest weed density m^{-2} respectively at harvest. The highest number of weeds per square meter was recorded in weedy check plots followed by 2, 4-D amine salt 0.75 L ha^{-1} for broad leaves, sedges and while the lowest weed population were recorded in weed free plot followed by post - emergence application of Bispyribac-sodium 10% SC 25 g ha^{-1} and Bispyribac-sodium 10% SC 20 g + 2, 4-D amine salt 0.75 L ha^{-1}. The proportion of grassy weed was higher than other weeds. Grasses persist in all of the principal crops and are a major cause for this distress. This is in accordance with the findings of [22]. The lower weed density with weed free and other herbicidal treatment might be due to inherent ability of the chemical to affect the cell division, cell growth and hampering the germination of weeds. The finding was in conformity with the finding of [23]. [24] and [25] they also reported similar results with herbicides application in rice.

iii. *Weed Dry Biomass*

The analysis of variance showed significant difference on the influence of herbicidal weed management practices on the weed dry matter at harvest. The data on dry weight of weeds at harvest was presented in Table 3. At harvest, minimum weed dry weight was registered with the application of 2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE it is also stastically at par with the Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE treatment. Herbicide application resulted in significant reduction in weed dry weight over weedy check. With the increase in Bispyribac-sodium 10% SC and 2, 4-D amine salt, the weed dry weight significantly decreased, while the results were inconsistent with the application of Bispyribac-sodium 10% SC 25 g ha^{-1} and 2, 4-D amine salt 1.0 L kg ha^{-1}. The rate of 2, 4-D amine

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salt and Bispyribac-sodium 10% SC application may depend upon soil types, rainfall and temperature. In contrast, weedy check plots recorded highest weed dry matter (525.33gm$^{-2)}$. [26] also reported that herbicide application decreased the dry biomass of weeds; however, this decrement depends on several factors, for example, duration of the crop, type of weed species, herbicides, fertilizer etc.

iv. *Weed control efficiency*

The highest weed control efficiency (86.7%) was recorded from 2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE which was in parity with Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE. The increasing rate for Bispyribac-sodium herbicide application proved more efficient than their lower rates of its application, thus; higher the weed control efficiency of a treatment, the greater was the weed control. The higher weed control efficiency could be attributed to the lower weed population and weed dry weight in these treatments. It is effective against many annual broad leaved and grassy weeds, resulting higher weed control efficiency. The results are in agreement with the findings of [27] and [9]. Among all the weed management practices, weed free plots recorded highest WCE, which might be due to decrease in weed biomass as compared to rest of the weed management practices. The highest WCE with weed free treatment also reported by [28], [29].

v. *Weed Index*

The highest weed Index (72.25%) was recorded with un weeded check, which indicated as by 72.25 per cent yield loss in un weeded check. Such yield losses due to weed competition was also reported by [30]. Among the herbicide treatments, Bispyribac-sodium 10% SC 25 g ha^{-1} (18.77%) was effective in reducing weed index followed by 2, 4-D amine salt 1.0 L kg ha^{-} (21.75 %) and Bispyribac-sodium 10% SC 20 g + 2, 4-D amine salt 0.75 L ha^{-1} (21.85 %). Better weed control efficiency and broad spectrum of control of these herbicides might have reduced weed index significantly. Similar results were reported by [31] and [30].

Table 3: Effect of weed management practices, on total weed density (m^{-2}) and dry biomass (gm^{-2}), weed control efficiency and Weed index at harvest of rice in 2017 cropping season

	Weed density	Weed dry biomass	WCE	WI
Weed management practices				
Bispyribac-sodium 10% SC 20 g ha^{-1}	156.67^{ab}	295.63^{b}	43.73^{b}	38.322^{b}
Bispyribac-sodium 10% SC 25 g ha^{-1}	80.00^{bcd}	124.93^{c}	75.66^{a}	18.77^{c}
Bispyribac-sodium 10% SC 30 g ha^{-1}	97.33^{abc}	136.43^{c}	74.21^{a}	27.88^{bc}
2, 4-D amine salt 0.75 L ha^{-1}	168.67^{a}	398.70^{ab}	27.33^{b}	60.85^{a}
2, 4-D amine salt 1.0 L kg ha^{-1}	72.00^{bcd}	107.11^{c}	79.29^{a}	21.75^{c}
2, 4-D amine salt 1.25 L ha^{-1}	71.67^{bcd}	133.03^{c}	74.35^{a}	29.53^{bc}
Bispyribac-sodium 10% SC 20 g + 2, 4-D amine salt 0.75 L ha^{-1}	80.00^{bcd}	123.06^{c}	76.34^{a}	21.85^{c}
Bispyribac-sodium 10% SC 10 g + 2, 4-D amine salt 1.0 L ha^{-1}	85.33^{abcd}	140.20^{c}	73.64^{a}	22.60^{bc}
Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE	70.00^{bcd}	98.86^{c}	82.20^{a}	15.56^{cd}
2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE	62.00^{cd}	66.26^{c}	86.71^{a}	18.21^{c}
Weed free check	0.00^{d}	0.00^{c}	100.00^{a}	0.00^{d}
Weedy check	133.33^{abc}	525.33^{a}	0.00^{c}	72.25^{a}
LSD (5%)	87.36	153.84	26.92	16.36
CV (%)	57.48	50.71	24.05	33.36

CV= coefficient of variation, DAE=days after crop emergence, LSD= least significant difference, Means in the same column followed by the same letters are not significantly different at 5% level of significance

b) Crop Parameters

i. *Phenology and growth*

a. *Days to 85 % physiological maturity*

The physiological maturity of the rice crop was significantly affected by weed management practices. Thus, the plants in plots treated with 2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE, Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE were significantly earlier in attaining 85% physiological maturity than the other treatments. The results also demonstrated that weed infestation

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throughout the growing period delayed 85% physiological maturity (Table 4). In conformity with this result, of [32] also identified that the plants in unweeded plots took the highest time to reach 90% physiological maturity. The result was in contrast to the findings of [33], who stated that treating plots with chemical and supplementing with hand weeding at intervals helped to reduce number of days to maturity in cowpea.

b. *Plant height*

Analysis of variance showed that the plant height was significantly affected due to the weed management practices. Application of herbicides alone or in combination with hand weeding resulted in significantly higher plant height than in weedy check (Table 3). The taller plant height of the treatments might be due to better nutrient utilization, accelerated cell enlargement and meristematic tissue development under least weed growth environment. This finding is in conformity with the findings of [28]; [34]. Comparable results were also reported by [35]. Similarly, in wheat plant height was remarkably increased by all weed management methods compared to weedy check [18].

Table 4: Effect of weed management practices on days to 50% flowering, days to 85% physiological maturity and plant height (cm) at harvest of rice in 2017 cropping season

	Days to 50% flowering	Days to 85 % physiological maturity	Plant height
Weed management practices			
Bispyribac-sodium 10% SC 20 g ha^{-1}	86.66^{ab}	117.66^{b}	79.80^{bcd}
Bispyribac-sodium 10% SC 25 g ha^{-1}	84.33^{ab}	115.33^{bc}	77.80^{bcd}
Bispyribac-sodium 10% SC 30 g ha^{-1}	84.33^{ab}	117.00^{bc}	87.53^{abc}
2, 4-D amine salt 0.75 L ha^{-1}	86.66^{ab}	118.33^{b}	66.73^{d}
2, 4-D amine salt 1.0 L kg ha^{-1}	85.66^{ab}	117.00^{bc}	95.53^{ab}
2, 4-D amine salt 1.25 L ha^{-1}	83.66^{b}	117.66^{b}	87.20^{abc}
Bispyribac-sodium 10% SC 20 g + 2, 4-D amine salt 0.75 L ha^{-1}	85.33^{ab}	118.33^{b}	78.93^{bcd}
Bispyribac-sodium 10% SC 10 g + 2, 4-D amine salt 1.0 L ha^{-1}	87.66^{ab}	117.66^{b}	74.33^{cd}
Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE	85.00^{ab}	115.66^{bc}	82.40^{abcd}
2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE	84.66^{ab}	115.33^{bc}	92.30^{abc}
Weed free check	83.66^{b}	113.66^{c}	100.33^{a}
Weedy check	88.33^{a}	122.00^{a}	43.13^{e}
LSD (5%)	4.25	3.48	18.20
CV (%)	2.93	1.75	13.35

CV= coefficient of variation, DAE=days after crop emergence, LSD= least significant difference, Means in the same column followed by the same letters are not significantly different at 5% level of significance

ii. *Yield components, yield and harvest index*

a. *Number of tiller per plant*

Number of tillers per plant recorded was significantly influenced by the weed control treatments imposed (Table 4). Weed free treatments registered highest number of tillers per plant which was significantly higher than weedy check. However, it was comparable with all other herbicides treatments, facilitating better utilization of plant nutrients by crop under reduced competition from weeds evident from better weed control efficiency and tiller production up to maximum tillering stage. The lowest number of tillers was registered with weedy check. These findings are in accordance with those of [35]. This is also in agreement with the findings of [36] and [28]. [37] observed that early post-emergence application of pyrazosulfuron-ethyl 10 to 15 g ha^{-1} significantly increased number of effective tillers per plant and grains per panicle. In contrast to this result, [38] reported that duration of weed interference did not significantly affect number of tillers per plant of irrigated common bean which could be due to more supply of water that might have increased the competitive ability of the crop.

b. *Panicle length per plant*

Analysis of variance showed that the effect of weed management practices had significant effect on panicle length (Table 4). Significantly lower number of tiller per plant, panicle length per plant and thousand seed weight (g) was recorded with weedy check. These are in conformity with the findings of [38]; [40] [41].

c. *Thousand Seed Weight*

The grains under Bispyribac-sodium 10% SC 25 g ha^{-1} plots recorded the highest weight (39.81g) which

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was statistically at par with 2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE, Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE (Table 4). The plants raised under weed free environment utilized available resources to their maximum benefit leading to increased seed weight. Similar to the current result, [42] also reported that thousand seed weight were increased with the increasing length of weed-free conditions and decreased with the increasing length of weedy conditions.

Table 5: Effect of weed management practices on Number of tiller per plant, Panicle length per plant and thousand seed weight (g) of rice in 2017 cropping season

	Number of tiller per plant	Panicle length per plant	Thousand seed weight (g)
Weed management practices			
Bispyribac-sodium 10% SC 20 g ha^{-1}	14.00^{abc}	10.40^{bc}	35.37^{bcd}
Bispyribac-sodium 10% SC 25 g ha^{-1}	17.06^{a}	12.60^{ab}	39.81^{a}
Bispyribac-sodium 10% SC 30 g ha^{-1}	13.40^{abc}	10.66^{bc}	37.27^{abcd}
2, 4-D amine salt 0.75 L ha^{-1}	11.13^{bc}	11.20^{bc}	33.22^{d}
2, 4-D amine salt 1.0 L kg ha^{-1}	15.26^{ab}	12.00^{abc}	37.06^{abcd}
2, 4-D amine salt 1.25 L ha^{-1}	13.13^{abc}	12.00^{abc}	36.42^{abcd}
Bispyribac-sodium 10% SC 20 g + 2, 4-D amine salt 0.75 L ha^{-1}	12.93^{abc}	10.06^{bc}	37.40^{abc}
Bispyribac-sodium 10% SC 10 g + 2, 4-D amine salt 1.0 L ha^{-1}	14.66^{ab}	12.53^{abc}	36.02^{abcd}
Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE	15.33^{ab}	12.86^{ab}	37.98^{ab}
2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE	14.93^{ab}	11.98^{abc}	39.63^{a}
Weed free check	18.13^{a}	14.20^{a}	39.14^{ab}
Weedy check	8.86^{c}	9.73^{c}	33.48^{cd}
LSD (5%)	5.30	2.84	4.07
CV (%)	22.27	14.39	6.52

d. *Grain Yield*

Grain yield of rice influenced significantly by various weed control treatments. The weed free treatment recorded significantly higher grain yield of 5701.9 kg ha^{-1}, among all the treatments. The weedy check treatment produced significantly lowest grain yield ha^{-1} among all the treatments. The weed free check treatment recorded 43.76% higher yield over weedy check. Similar finding was reported by [43] and [44]. Among chemical method of weed control, significantly higher grain yield of 4776.5 kg ha^{-1} was produced with Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE which was at par with 2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE (4618.0) and Bispyribac-sodium 10% SC 25 g ha^{-1}(4612.5); those treatments recorded with 41.06 %; 40.41 % and 40.27 higher yield over weed check respectively (Table 5). The increased grain yield with these treatments is due to reduced weed density, weed biomass and better weed control efficiency along with improvement in yield attributes like number of effective tillers per plant, panicles length, and 1000 grain weight. This corroborates with the findings of [45]. On the other hand, significantly lower yield was obtained in weedy check than the other treatments. The minimum yield in unweeded check is the result of severe weed competition by uncontrolled weed growth. Similar findings were also reported by [22].

e. *Aboveground Dry Biomass Yield*

Like grain yield, the aboveground dry biomass yield was also highly affected by weed management practices. The highest aboveground dry biomass yield (10797 kg ha^{-1}) was obtained in 2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE treated plots which was statistically at par with 2, 4-D amine salt 1.0 L kg ha^{-1}, Bispyribac-sodium 10% SC 25 g ha^{-1} at all the application rates, and all the herbicide mixtures. Weedy check plots had the lowest aboveground dry biomass yield among the treatments (Table 5). Prolonged weed competition resulted in reduced biomass accumulation and lesser panicle length per plant and thousand seed weight which ultimately translated into lower grain yield. Increased biomass accumulation by weeds with the increasing span of weed interference period might also be a plausible cause of yield reduction in rice. As [46] stated, weed dry matter has been found to be highly correlated with crop yield loss.

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f. *Harvest Index*

The result indicated that there was significant variation on harvest index among the weed management treatments evaluated. Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE gave the highest harvest index (45.13%) while the lowest harvest index (26.85%) was recorded for weedy check (Table 3). The findings of present study are in conformity with the results obtained by [47]; [48] and [49].

g. *Yield Loss*

The weeds under different weed management treatments caused variability in the amount of grain yield loss in rice. The highest yield loss (62.44%) was recorded in weedy check. This was statistically in parity with the loss registered with the application of 2, 4-D amine salt 0.75 L ha^{-1}. All these weed management practices recorded a significant yield loss compared to other treatments. Weeds are the principal limiting biological factor in global rice production, with losses that vary from country to country, depending on the cultivation system, predominant weed communities and weed control methods employed by the farmers [50]. Worldwide, it is estimated that weeds cause 9% of rice crop losses [51], with reductions in rice paddies of 94% to 96% in the Philippines [10]; in Colombia, losses of 30% to 73% have been reported [52]. Appropriate control methods in rice crops are essential to minimize the negative effect of weeds [53]. This difference in decrease in rice yield reported by various researchers might be due to the differences in weed flora, crop varieties and environmental conditions prevailing in the study area. Therefore, the difference in time of weed removal might have contributed to this variation in yield. The herbicides might have dissipated soon from the soil under the influence of environmental conditions prevailing during the crop season.

Table 6: Effect of weed management practices on grain yield, aboveground dry biomass, harvest index and yield loss of rice in 2017 cropping season

	Grain Yield	Aboveground Dry Biomass Yield	Harvest Index	Yield Loss
Weed management practices				
Bispyribac-sodium 10% SC 20 g ha^{-1}	3554.3^{c}	10490.8^{a}	35.72^{abc}	40.71^{ba}
Bispyribac-sodium 10% SC 25 g ha^{-1}	4612.5^{b}	11043.6^{a}	41.90^{a}	22.17^{b}
Bispyribac-sodium 10% SC 30 g ha^{-1}	4085.2^{bc}	11141.4^{a}	38.15^{ab}	32.96^{b}
2, 4-D amine salt 0.75 L ha^{-1}	2223.6^{d}	8820.9^{bc}	29.87^{bc}	56.01^{a}
2, 4-D amine salt 1.0 L kg ha^{-1}	4468.2^{bc}	10791.2^{a}	41.34^{a}	24.78^{b}
2, 4-D amine salt 1.25 L ha^{-1}	4038.5^{bc}	10314.5^{ab}	38.98^{ab}	32.28^{b}
Bispyribac-sodium 10% SC 20 g + 2, 4-D amine salt 0.75 L ha^{-1}	4440.8^{bc}	11029.6^{a}	40.20^{ab}	27.25^{b}
Bispyribac-sodium 10% SC 10 g + 2, 4-D amine salt 1.0 L ha^{-1}	4385.9^{bc}	10585.5^{a}	41.40^{a}	26.91^{b}
Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE	4776.5^{b}	10558.4^{a}	45.13^{a}	21.38^{b}
2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE	4618.0^{b}	11665.8^{a}	41.72^{a}	22.03^{b}
Weed free check	5701.9^{a}	10705.2^{a}	45.63^{a}	18.68^{b}
Weedy check	1580.4^{d}	8439.1^{c}	26.85^{c}	62.44^{a}
LSD (5%)	919.32	1568.9	11.15	22.26
CV (%)	13.43	8.85	16.92	

CV= coefficient of variation, DAE=days after crop emergence, LSD= least significant difference, Means in the same column followed by the same letters are not significantly different at 5% level of significance

c) *Partial Budget Analysis*

The result of the partial budget analyses showed that Weed free check accrued 25.5 and 26.6% higher total variable cost than Bispyribac-sodium 20 g ha^{-1} and 2, 4-D amine salt 0.75 L ha^{-1} both superimposed with hand weeding, respectively (Table 6). On the other hand the highest net benefits were obtained with the application of Bispyribac-sodium 10% SC 25 g ha^{-1}, followed by 2, 4-D amine salt 1.0 L kg ha^{-1}.

In agreement with the result, most studies showed that, applying herbicide or herbicide plus manual weeding was more economical than manual or hand weeding alone [54].

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Table 7: Results of partial budget analysis of weed management practices in rice in 2017 cropping season

	Average yield (kg ha^{-1})	Adjusted yield (kg ha^{-1}) 10% down	Total variable cost (ETB ha^{-1})	Gross return (ETB ha^{-1})	Net return (ETB ha^{-1})
Weed management practices					
Bispyribac-sodium 10% SC 20 g ha^{-1}	3554.3	3199	8708	47983	39275
Bispyribac-sodium 10% SC 25 g ha^{-1}	4612.5	4151	10217	62269	52052
Bispyribac-sodium 10% SC 30 g ha^{-1}	4085.2	3677	9565	55150	45585
2, 4-D amine salt 0.75 L ha^{-1}	2223.6	2001	6912	30019	23107
2, 4-D amine salt 1.0 L kg ha^{-1}	4468.2	4021	10022	60321	50299
2, 4-D amine salt 1.25 L ha^{-1}	4038.5	3635	9502	54520	45018
Bispyribac-sodium 10% SC 20 g + 2, 4-D amine salt 0.75 L ha^{-1}	4440.8	3997	10025	59951	49926
Bispyribac-sodium 10% SC 10 g + 2, 4-D amine salt 1.0 L ha^{-1}	4385.9	3947	9951	59210	49259
Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE	4776.5	4299	14108	64483	50374
2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE	4618	4156	13894	62343	48449
Weed free check	5701.9	5132	18948	76976	58028
Weedy check	1580.4	1422	2134	21335	19202

The hand wedding is laborious and generally more expensive. From the computation of weed control cost it was observed that the maximum cost of weed control (11250 ETB ha^{-1}) was required for the treatment weed free check which was due to maximum labour requirement followed by Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE, 2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE which may be due to high volume of herbicide and labour cost. Similar results on the weed control costs were as also observed by [25].

In weed free check, the benefit cost (3.1) was lesser even though the grain yield and gross returns were higher and was due to higher cost of cultivation as a result of high cost incurred towards labour for weeding (Table 5). Due to the severe crop weed competition throughout the crop growth period resulting in decreased growth and yield contributing parameters. Similar finding was observed by [54]. These results are also in conformity with the findings of [48] and [56].

IV. Conclusion And Recommendations

Rice is a newly introduced crop in Ethiopia. However, its importance is increasing as evidenced by the increasing in production and area covered. Due to the nature of the crop and its high productivity than other field crops, rice production in *Guraferda* district has been increasing and contributing both for income and food security of farmers. Weeds are the principal limiting biological factor in global rice production, with losses that vary from country to country, depending on the cultivation system, predominant weed communities and weed control methods employed by the farmers. Hence, the experiment was conducted in Southern Nations Nationalities Peoples Region, Ethiopia during the 2017 main cropping *'Meher'* season, in Bench Maji Zone at *Guraferda Woreda* research site. The e objectives of the study were to find out the effect of Bispyribac-sodium 10% SC, and 2, 4-D amine salt on weeds, growth, yield components and yield of rice and to investigate the possibilities of supplementing low doses of herbicides with hand weeding for effective weed control.

New Rice for Africa variety four was used for this experiment. The research was consisting of 12 treatments *Viz*: Bispyribac-sodium 10% SC (20 g ha^{-1}), Bispyribac-sodium 10% SC (25 g ha^{-1}), Bispyribac-sodium 10% SC (30 g ha^{-1}), 2, 4-D amine salt (0.75 L ha^{-1}), 2, 4-D amine salt (1.0 L kg ha^{-1}), 2, 4-D amine salt (1.25 L ha^{-1}), Bispyribac-sodium 10% SC 20 g + 2, 4-D amine salt 0.75 L ha^{-1}, Bispyribac-sodium 10% SC 10 g + 2, 4-D amine salt 1.0 L ha^{-1}, Bispyribac-sodium (20 g ha^{-1}) + hand weeding and hoeing at four-five weeks after crop emergence, 2, 4-D amine salt (0.75 L ha^{-1}) + hand weeding and hoeing at four- five weeks after crop emergence, Weed free check, Weedy check. The design of the experiment was RCBD with three replications.

The most important weeds in the experimental fields were broadleaved, grassy and sedges. The influence of herbicides on weed density was clearly visible at harvest. The lowest weed dry weight was recorded with the application of 2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE it is also stastically at par with the Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE treatment. The

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highest weed control efficiency 86.7% was recorded from 2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE which was in parity with Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE. Among the herbicide treatments, Bispyribac-sodium 10% SC 25 g ha^{-1} 18.77% was effective in reducing weed index followed by 2, 4-D amine salt 1.0 L kg ha^{-} 21.75 % and Bispyribac-sodium 10% SC 20 g + 2, 4-D amine salt 0.75 L ha^{-1} 21.85 %.

The results also confirmed that weed infestation throughout the growing period delayed 85% physiological maturity. Significantly lower number of tiller per plant, panicle length per plant and thousand seed weight was recorded with weedy check. The weed free check treatment recorded 43.76% higher yield over weedy check. Among chemical method of weed control, significantly higher grain yield of 4776.5 kg ha^{-1} was produced with Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE which was at par with 2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE (4618.0) and Bispyribac-sodium 10% SC 25 g ha^{-1} 4612.5, those treatments recorded with 41.06 %; 40.41 % and 40.27 higher yield over weed check respectively. Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE gave the highest harvest index (45.13%) while the lowest harvest index (26.85%) was recorded for weedy check. The highest yield loss 62.44% was recorded in weedy chec. The outcome of the partial budget analyses indicated that weed free check increased 25.5 and 26.6% higher total variable cost than Bispyribac-sodium 20 g ha^{-1} and 2, 4-D amine salt 0.75 L ha^{-1} both superimposed with hand weeding, respectively. On the other hand the maximum net benefits were acquired with the application of Bispyribac-sodium 10% SC 25 g ha^{-1}, followed by 2, 4-D amine salt 1.0 L kg ha^{-1}. The hand wedding is laborious and generally more expensive. If cheaper and ample labour are available Bispyribac-sodium 10% SC 20 g ha^{-1} + hand weeding and hoeing at 35 DAE should be done. With the availability of herbicides, Bispyribac-sodium 10% SC 25 g ha^{-1} followed by 2, 4-D amine salt 1.0 L kg ha^{-1} can be used to preclude the yield loss and to obtain maximum benefits from rice.

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Economic Valuation of Parthenium Weed Control Measures, in Gurage Zone, SNNPR of Ethiopia

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Abstract- The study was initiated to estimate the monetary value that farmer households' are willing to pay for the control measure of Parthenium weed and to identify the factors determining their level of willingness to pay amount. The primary data were collected from 320 sample households drawn randomly from two purposively selected districts, Abeshige and Kebena (160 from each districts), in Gurage zone, SNNPR of Ethiopia. Both descriptive statistics and Tobit model were used to analyze the data. To elicit and estimate farmers' responses on the amount of willingness to pay for the control measures of Parthenium weed, a contingent valuation approach involving a single bound with open ended follow up format was used. Accordingly, the estimated mean WTP for the control measure of Parthenium weed was estimated to be 168.52birr per year per household. In addition, the total maximum willingness to pay (which consists of 6,742 households in all sampled kebeles from both districts) was estimated to be 795,313.288 birr per year. The Tobit model estimates revealed that age, education, livestock ownership, off/non-farm sources of income, past awareness, assistance and membership were found to be the most important determinant factors that affect households' maximum willingness to pay for the control measures of Parthenium weed in the study area.

Keywords: invasive alien plant species (IAPS), parthenium weed, economic valuation, contingent valuation method (CVM), gurage zone.

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Mekdes Dessie [α] & Dawit Moges [σ]

Abstract- The study was initiated to estimate the monetary value that farmer households' are willing to pay for the control measure of Parthenium weed and to identify the factors determining their level of willingness to pay amount. The primary data were collected from 320 sample households drawn randomly from two purposively selected districts, Abeshige and Kebena (160 from each districts), in Gurage zone, SNNPR of Ethiopia. Both descriptive statistics and Tobit model were used to analyze the data. To elicit and estimate farmers' responses on the amount of willingness to pay for the control measures of Parthenium weed, a contingent valuation approach involving a single bound with open ended follow up format was used. Accordingly, the estimated mean WTP for the control measure of Parthenium weed was estimated to be 168.52birr per year per household. In addition, the total maximum willingness to pay (which consists of 6,742 households in all sampled kebeles from both districts) was estimated to be 795,313.288 birr per year. The Tobit model estimates revealed that age, education, livestock ownership, off/non-farm sources of income, past awareness, assistance and membership were found to be the most important determinant factors that affect households' maximum willingness to pay for the control measures of Parthenium weed in the study area. There is a need to linkage creation and collaboration development between and/or among all concerned body's and stakeholders and designing and implementing integrated Parthenium weed prevention/ controlling packages with full participation of the farmer households' in the study area. Finally, priority should also be given to urgently continue with the control or eradication of Parthenium weed, to avoid future costs which may result if the control of this weed remains suspended.

Keywords: invasive alien plant species (IAPS), parthenium weed, economic valuation, contingent valuation method (CVM), gurage zone.

I. Introduction

Worldwide in general in Ethiopia in particular, agriculture holds many future challenges to adapt with such as global warming [1], resource shortages and invasive alien plant species [2]. Invasive alien plant species (IAPS) are plants that are non-native to an ecosystem and which may cause economic or environmental harm or adversely affect human health (The Convention on Biological Diversity, 2009). IAPS may also be termed as weeds, that is, plants that are objectionable or interfere with the activities and welfare of people [3]. Invasive species are of concern because of their capability of spreading fast, their high competitiveness and ability to colonize new areas within short periods. The nature and severity of the impacts of these species on society, economic life, health and national heritage are of global concern [4].

Globally, the cost of damage caused by invasive species has been estimated to be $1.5 trillion per year – close to 5% of the global GDP [5]. In developing countries, where agriculture accounts for a higher proportion of GDP, the negative impact of invasive species on food security as well as on economic performance can be even greater. Virtually all ecosystem types on the planet are affected by invasive species and they pose one of the biggest threats to biodiversity worldwide. They reduce yields of agricultural outputs both crop and livestock, forest land, fishery, decrease water availability and contribute to spread of disease. As a result, IAPS contributes to social instability and economic hardship, placing constraints on sustainable development, economic growth, poverty alleviation and food security [6].

Ethiopia is among the developing African countries affected by IAS. This is reflected in the fact that IAS has been clearly identified as one of the emerging problems facing the country over the last two decades [7]. Several alien species are spreading at alarming rate, and threatening agricultural lands, rangelands, national parks, lakes, rivers, power dams, and urban green spaces - causing huge economic and ecological losses [8]. Foremost among these invasive plant species is Parthenium *hysterophorus L.* (Parthenium), which is an emerging problem in Ethiopia; the weed has been spreading throughout the country after it was first noticed around Dire Dawa in 1980's [9] and [10].

The impacts of Parthenium are numerous and are most profound on agriculture, environment and human health. Studies in some other parts of the world have shown that impact of Parthenium invasion on animal and human health as well as the economic loss in agriculture [6]. Crop losses are caused primarily through allelopathic effects over and above its ability to compete for nutrients and moisture and these losses are

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often proportionally higher than expected from a similar crop weed. Another mechanism by which Parthenium impacts upon crop productivity is through its ability to cover crops in pollen, which prevents seed set with resulting losses in yields of up to 40% [11]. Which indicates the existence of Parthenium is a growing danger to small-scale farmers. If it is not controlled on time, it will occupy the land alone.

Under controlled experiments, at high densities, yields showed a 97 percent decline [12]. Estimates show that between one and two million hectares of farming land (up to 2 per cent of the land area) is affected in Ethiopia [10]. Furthermore, it increases production costs and thereby lowers the profitability of farm enterprises and driving farmers to poverty. In addition to direct competition for resources and allelopathic effects, Parthenium causes health hazard to humans and animals. In general there is fear that the rapid and uncontrolled expansion of the weed may considerably weaken the carrying capacity of the grazing land [13]. While the adverse impacts of Parthenium weed on native habitats have become an issue of global concern, there remains a gap in the understanding of the weed in many areas of the world including Ethiopia [14]. The weed is currently invading almost all regions of the country at an alarming rate [15]. Attempts have been made both at national and regional levels to mitigate this problem which has a direct causal effect to declining agricultural productivity and food insecurity. However, problems have been more serious and critical than ever before and threaten many people's lives in the country as well as in the study area.

Though, there are no precise data available on the current infestation level of Parthenium weed in the region its distribution is widely increasing with its detrimental effect on agricultural productivity and production as it can be seen from ground reality. In the study area (Gurage zone) almost all kebeles are highly invaded by Parthenium. Consequently, people are now facing challenges and problems due to the spreading of the weed. Much of the studies conducted on Parthenium focused on biological aspects such as distribution, diversity, biological control etc. Effort has not been made to assess farmers' perception of the socio-economic impact of Parthenium and the interrelated socio-economic and physical factors that determine farmers' participation in the preventive and control measures at household level.

The major problems encountered in the past and current control activities were related with wrong perception towards the problem, poor participation of community members because of the externalization of the issue, lack of sustainability of control programs, lack of enforcement mechanisms, resource limitations, unavailability of a recommended package of control techniques; shortage/unavailability of information, shortage of trained manpower, lack of an institutional set up for designing and implementing Parthenium control programs and lack of proper national attention to control Parthenium, poor coordination among stakeholders [14].

Formulation of control measure strategies for environmental protection from such kind of invasive weeds demands the participation of farmers (in terms of their willingness to contribute) from the very beginning. Accordingly, identification of factors that influence farmers' WTP for control measures of Parthenium weed, can help policy makers, practionaires and other stakeholders to take appropriate action in formulating strategies that curb the problem of invasion by Parthenium with active participation of farmers. Hence, this study was initiated to estimate the value farmers' are willing to pay for the control measure of Parthenium weed, and identify factors determining farmers' willingness to pay for control measure of Parthenium weed in Gurage zone, SNNPR of Ethiopia.

II. Research Methodology

a) *Description of the study area*

This study was undertaken in Abeshige and Kebena districts of Gurage zone in SNNPR of Ethiopia. Abeshge district is situated between 8.19'- 8.43' North latitudes and 37.45'-38.89' East longitudes. The topography of Abeshge district varies from 1001-2000 masl. The annual average temperature ranges from 15.5 - 25 ^{o}c while the total annual rainfall varies between 801mm and 1400mm. These situations resulted in a diverse agro-ecology which is suitable for the production of various annual crops (such as *teff*, maize and sorghum), perennial crops (such as coffee and khat) and livestock. The district covers a total area of 559 km^2. The district has an estimated population of 68,598 of which 36,240 are male and 32,358 are female. The district consists of 26 kebeles, of which constitutes only two of them are urban. On the other hand, Kebena district is situated between 8.22' - 8.39' North latitudes and 37.72' - 38.13' East longitudes. The topography of Kebena district varies from 1501-2000 masl. The annual average temperature ranges from 17.6 – 20^{o}c while the total annual rainfall varies between 1201mm and 1400mm. These situations resulted in a diverse agro-ecology which is suitable for the production of various annual crops (such as *teff*, barley, maize and sorghum), perennial crops and livestock. The district covers a total area of 298 km^2. The district consists of 23 rural based administrative kebeles. The district has an estimated population of 58,496 [26].

b) *Sampling procedure and methods of data collection*

The study employed multi stage purposive and random sampling techniques to draw a representative sample. At the first stage, the two districts (Abeshige and Kebena) were selected purposively. At the second stage, four kebeles (Sunika Dinicho,

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Katibare, Tatesa Weshribe and Odobera) from Kebena and five kebeles (Darge, Mida Tedele, Nacha Qulit, Hudad 5 Ena 6 and Gibe) from Abeshige districts were purposively selected. Finally, on the basis of probability proportional to size (PPS) of the number of farmers in each selected kebeles, a total sample size of 320 farmer households (160 from each selected districts) were randomly drawn.

Both primary and secondary data sources were used in this study. The Primary data was collected using Focus Group Discussion (FGD) and structured questionnaires. The FGD was conducted using some purposively and randomly selected key informants and households from the above selected kebeles in both districts to determine the appropriate threshold value/price. To elicit farmers' responses on the amount of WTP, the study used a contingent valuation method (CVM) involving a single bound with open ended follow up question [27].

c) Methods of data analysis

i. *Descriptive analysis*

a. Estimating Aggregate Maximum WTP Value

An important issue related to the measurement of welfare using WTP is aggregation of benefit [28]. Accordingly, the maximum figures for the WTP reported by the respondents can simply be averaged to produce an estimate of Mean Maximum WTP:

$$\text{Mean MWTP} = \sum y_i/n \qquad \ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where: n is the sample size and each **y** is a reported WTP amount by the surveyed farmers

b. Estimating Total Maximum WTP

The estimation of total social benefits from the environmental protection (Parthenium weed control measures in this case) is conventionally carried out by estimating the aggregate of individual WTP [29]. Accordingly, it was calculated using the following formula:

$$WTP_{total} = WTP_{hh} * HH * R_{wtp} \qquad \ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where: WTP_{total}, is the total amount of WTP that households in both districts are willing to pay per year; WTP_{hh}, is the mean annual household WTP; HH denotes the total number of households in both districts and R_{wtp}, is the percentage of respondents' willing to pay.

ii. *Econometric Analysis*

Since the value of dependent variable (Maximum WTP for the control measure of Parthenium weed) in this study is all positive values, the Ordinary Least Square method [30]. will not yield consistent estimates. A widely used approach, the Tobit model [31] was developed to alleviate the problems caused by OLS. In this study, therefore, Tobit model is employed to identify factors determining the decision and the amount that a household is willing to pay for the control measure of Parthenium weed in the study area.

The general form of Tobit Model, when lower limit is censored to zero, can be defined as:

$$y_i^* = \beta X_i + u_i \qquad \text{For, } i = 1, 2, \ldots\ldots, n$$

$$y_i = y^* \; if \; y_i^* > 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots 3$$

$$y^* = 0 \; if \; y_i^* \leq 0$$

$$\text{With } u_i \sim N(0, \sigma^2)$$

Where:

$$\boldsymbol{y_i} = the\ observed\ maximum\ WTP\ for\ the\ control\ measure\ of\ parthenium\ weed;$$

$\boldsymbol{y^*}$ = *the latent or unobserved willingness to pay for control measure of Parthenium weed;*

$\boldsymbol{X_i}$ = *a vector of explanatory variable (socio-economic, demographic and institutional factors) and* $\boldsymbol{\beta}$ = *a vector of unknown parameters*

$\boldsymbol{u_i}$ = *residuals that are independently and normally distributed with mean zero and a common variance,* σ^2.

The Tobit coefficients do not directly give the marginal effects of the explanatory variables on the dependent variable [32]. Hence, one has to compute the derivatives of the estimated Tobit model to predict the effects of changes in the exogenous variables. Thus, a change in $\mathbf{X_i}$ (explanatory variables) has two effects. It affects the probability that the observation will fall in that part of the distribution and it affects the conditional mean of Y_i^* in the positive part of the distribution. Following the works of [33] similar approach is used in this study.

III. Results and Discussion

a) Results of the Descriptive Analysis

Out of the total 320 sampled households taken in both districts, about 224 respondents were willing (WTP) and 96 were not willing to pay (NWTP) for the control measure of Parthenium weed.

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Table 1: Descriptive statistics result of households demographic, socio-economic and institutional characteristics in both districts (N=320)

Variables category								
Dummy variables		WTP (224) Frequency	%	NWTP (96) Frequency	%	Total (320) Frequency	%	χ^2-value
SEXHH	Male	208	65	40	12.5	248	77.5	- 0.702
	Female	16	5	56	17.5	72	22.5	
OFFARINC	Yes	120	37.5	8	2.5	128	40	16.182***
	No	104	32.5	88	27.5	192	60	
PASTAWERPP	Yes	72	22.5	48	15	120	37.5	5.614***
	No	152	47.5	48	15	200	62.5	
LANDTENURE	Yes	66	20.6	84	26.3	150	46.9	2.406
	No	158	49.4	12	3.75	170	53.1	
IMPACT	Yes	149	46.6	18	5.6	167	52.2	9.398***
	No	75	23.4	78	24.4	153	47.8	
ASSISTANCE	Yes	80	25	10	3.1	90	28.1	4.211**
	No	144	45	86	26.9	230	71.9	
ATITUDTOPAY	Yes	48	15	66	20.6	114	35.6	-0.170
	No	176	55	30	9.4	206	64.4	
MEMBSHIP	Yes	161	50.3	28	8.7	196	59	4.890**
	No	63	19.7	68	21.3	131	41	

Continuous variable	WTP (224) Mean	WTP (224) StD.	NWTP (96) Mean	NWTP (96) StD.	Total (320) Mean	Total (320) StD.	t-value
AGEHH (in years)	42.95	5. 39	48.12	1.88	45.1	5. 52	7.586***
EDULHH (in years of schooling)	7.25	0.52	4.28	1.87	5. 87	2. 83	2.524**
FAMSIZHH (in adult equivalent)	5.39	1.98	2.5	0.52	5.25	2.04	5.818***
LIVSTOWN (in TLU)	5.46	0.71	2.62	0.44	5.32	1.71	4.202*
LANDSIZE (in ha)	4.08	0.74	2.5	0.59	3.25	1.41	-4.625

***, **,*show significance level at 1%, 5% and 10% probability levels, respectively.

Source: Survey data result, 2017.

As it is shown in the above table (in Table 1) the descriptive result showed that the willing and not willing households differed significantly from each other in age, education, family size, livestock ownership, engagement in any off/non-farm sources of income, past awareness on prevention technology methods, impact of Parthenium weed encountered, assistance (training and extension service) and membership of the households in cooperative organizations.

b) Estimating the Maximum Mean and Total WTP value

The mean maximum WTP amount for 320 households was found to be 168.52 birr per annum per household. The aggregate maximum WTP was calculated by multiplying the mean MWTP by the total 320 sampled household respondents. Following the formula and procedure (in equation 3), the aggregate Maximum WTP for Parthenium weed control measures was computed to be 53,926.4 birr per year. Similarly, following the formula and procedure (in equation 4) the total maximum amount that households' (6,742 households' in both districts) are willing to pay per year for the control measure of Parthenium weed was found to be 795,313.288 birr per year.

c) Results of Econometric Analysis

Prior to running the Tobit model, the hypothesized explanatory variables were checked for the existence of multicollinearity and heteroscedasticity. The Tobit model shown below (in table 2) estimates the parameters of the variables which are expected to determine the probability to affect farmer Maximum WTP and the intensity level/amount of payment for the control measure of Parthenium weed.

From the Tobit model output indicated in the Table 2 below, it is observed that seven variables (age, education, live stock ownership, off farm income, past awareness, assistance and membership) were significantly influenced the probability of households' maximum WTP and intensity of payment among individuals. Since, direct interpretation of the Tobit model output (presented in Table 2) is not straightforward, the study used three set of marginal effects (only the significant variables incorporated) for interpretation and report purpose: the effect on the probability of a positive WTP, the effect on conditional WTP (among willing respondents) and the effect on unconditional WTP (among all willing and unwilling respondents), which is presented in Table 3.

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Table 2: MLE of the Tobit model for Factors Affecting Farmers' WTP in both districts

Variables	Coefficients	t-ratio
Sex	-24.92	-0.65
Off farm income	78.491	2.97***
Past awareness	79.687	1.74*
Impact of land tenure	-37.536	-0.94
Impact of Parthenium	58.84	4.19
Assistance	124.011	3.6***
Attitude to pay	1.967	0.31
Membership	13.097	3.28***
Age	-4.487	-2.26**
Education	73.102	2.31**
Family size	5.632	0.59
Live stock ownership	16.989	1.75*
Total land size	-9. 3218	-9.19
Cons	84.686	0.80
Number of observation	320	
Prob > chi2	0.0000	
Pseudo R2	0.3146	
LR chi2(13)	413.72	

***, **,*, shows significance level at 1%, 5% and 10% probability levels, respectively

Source: Survey data result, 2017.

According to the result of the Tobit model marginal effect showed below (in table 3) age has a negative and significant influence on the probability of maximum WTP. The result implies that as a household becomes older, the probability of willingness to pay for the control measure of Parthenium weed will decrease by 0.07%, ceteris paribus. This might be because aged farmers at later age lack resources (money) even though it is hard to generalize, if aged people had money they may not be interested to pay or invest in environmental protection, since such investment may take long time before its maturity to give return [8] and [14].

Table 3: Marginal effects of the explanatory variables

Variables	The Change in the probability of WTP as independent variable X_i changes: $\frac{\partial F(Z)}{\partial X_i}$	The change in amount of WTP with respect to a change in an explanatory variable among willing respondents: $\frac{\partial E(y_i/y_i^* > 0)}{\partial X_i}$	The marginal effect of an explanatory variable on the expected value of the dependent variable (change among all) is: $\frac{\partial E(Y_i)}{\partial X_i}$
Age	-.0007**	-4.193**	-4.440**
Education	.0128*	67.735**	72.193**
Live stock ownership	.0026*	15.883*	16.820*
Off farm income	.0112**	73.654***	77.725***
Past awareness	0121*	74.457*	78.851*
Assistance	.0127***	118.276***	123.165***
Membership	.0241 **	5.408***	11.316***

****, **,*, shows significance level at 1%, 5% and 10% probability levels, respectively*

Education had a positive and significant relationship with maximum amount of WTP at 10% probability level. This suggests that, as households become more educated the probability of willingness to pay for the control measure of Parthenium weed will increase by 1.28%, ceteris paribus. The result is in line with the findings of [34], [35] and [36].

A unit increase in the number of livestock (in TLU) an individual owns will increase the probability of willingness to pay by 0.26% (at 10% probability level).

This might be due to the fact that the number of Livestock holding could be a proxy for wealth under Ethiopian farmers' condition. When the wealth of a household increases, the Willingness to pay will also

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increase (Animut, 2007). The implication might be as Parthenium is observed to have an adverse and different kind of impact on livestock production and productivity. Therefore, farmers who owned a large number of livestock are more likely to be WTP and invest more on the control measures of this weed.

As households' engaged in any off/non-farm sources of income/employment, the probability of maximum WTP increases by 1.12% (at 5 % probability level of significance). This is in line with the basic economic theory, which states that individuals demand for most goods or services depends on income [37].The other possible explanation for this result is, this is because income sources from any off-farm activities would contribute to the improved welfare of the households and able them to relieve different financial constraints [38] and thereby increases their WTP. In addition, the study result is in line with the findings by [39].

Households' awareness on the impact and in the available option on the effective control and prevention method of Parthenium weed known and undertaken in the past, which is a proxy for management or control technology awareness, found to affect the probability of farmers' maximum amount of WTP positively and significantly (at 10% probability level). The result implies that as a household becomes aware, the probability of WTP for the control measure of Parthenium weed will increase by 1.21%, ceteris paribus.

As it is indicated the variable assistance (in the form of extension service and training) increases the probability of WTP by 1.27 % at 1% probability level of significance. Extension provides farmers with information related to better agricultural farming practices and technologies while protecting their natural resource which improves their knowledge and thus awareness of the need to protect and manage the resource [40].With regard to training; a study by [41] showed that it was positively associated with willingness to pay. As farmers received any form of assistance in the prevention and control measures had positively influenced farmers' maximum WTP amount by birr 118.28 and 123.16 among willing and the entire sample respondents, respectively.

IV. Conclusion And Recommendation

The study estimated the economic value farmers' are willing to pay for the control measure of Parthenium weed and examined the factors that determine their maximum WTP amount of money for the control measures of Parthenium weed in Abeshige and Kebena districts, Gurage zone. To achieve the above mentioned objectives both primary and secondary data were used. The Primary data were collected from 320 randomly sampled farmer households' from the two districts (160 from each) using a structured questionnaire. To elicit the maximum amount farmers are WTP the study used a single bound with open ended follow up CVM. The data obtained was analyzed using both descriptive and econometric methods. Accordingly, the result of the study showed that about 224 respondents were willing and 96 were not willing to pay for the control measure of Parthenium weed. The result of the estimated mean maximum WTP value of controlling Parthenium weed was found to be 168.52 birr per year per household. In addition, the total maximum willingness to pay from the total population in both districts (6, 742 households) was estimated to be birr 795,313.288 birr per year.

The simultaneous Tobit analysis result indicated that, age, education level, livestock ownership, off/non-farm sources of income, past awareness, assistance and membership in any form cooperatives were found to significantly affect farmer households' willingness to pay. Thus, these factors have important policy implications in that due emphasis should be given to these important policy variables. Accordingly, it can be concluded that understanding and addressing of these factors is a necessary and first step before designing and implementing the most effective measures/ strategies to control or eradicate Parthenium weed in the study area.

Therefore, based on the results obtained the following important policy recommendations can be suggested to control or eradicate Parthenium weed in the study area:

- The study first and foremost, underlined the crucial importance of creating and raising or improving farmer households' awareness and knowledge about the adverse impact of Parthenium weed through different outreach methods and instruments so as to promote their maximum willingness to pay for the most effective strategies/packages to control or eradicate this weed.
- There is also a need to linkage creation and collaboration development between and/or among all concerned body's and stakeholders and designing and implementing integrated Parthenium weed controlling packages with full participation of farmer households' in the study area.
- In addition, making, implementing and strengthening of policies and strategies that encourages or promotes farmers to form or join farmer associations (particularly in the form of cooperatives) and that support the expansion and promotion of off-farm sources of income/ employment are among others will be a step in the right direction in this regard.
- Furthermore, farmers' capacity building programs to asset formation or accumulation should be strengthened.
- Finally, priority also should be given to urgently continue with the control or eradication of

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Parthenium weed, to avoid future costs which may result if the control of this weed remains suspended.

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Effects of Tillage Practices, Cropping Systems and Organic Inputs on Soil Nutrient Content in Machakos County, Kenya

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Abstract- Low use efficiencies of inorganic fertilizers coupled with their rising costs has diverted attention of farmers towards organic sources. Against this backdrop, a study was conducted in Matuu in Yatta sub-county, Machakos County, to evaluate the influence of tillage practices, cropping systems and organic inputs on soil nutrient status. The study was carried out between October 2012 to February 2013 short rains (SRS) and April-August 2013 long rainy seasons (LRS). ARandomized Complete Block Design with a split-split plot arrangement replicated three times was used where the main plots were the tillage practices (TP): Oxen plough (OP), Tied ridges (TR) and Furrows and Ridges (FR). The split-plots comprised the cropping systems (CS): Mono-cropping (MC), Intercropping (IC), and Crop rotation (CR) while split-split plots were organic inputs: Farmyard manure (FYM), Minjingu Rock Phosphate (MRP), combined MRP and FYM (MRP+FYM) plus the Control. The test crops were sorghum and sweet potatoes (Impomea batata) with Dolichos (Dolichos lablab) and chickpea (CicerarietinumL.) added either as intercrops or in rotation. Soil samples were taken randomly at 0-30 cm depth at the onset of the experiment and at maturity of test crop for soil (NPK and %OC) analysis. There was a significant ($P \leq 0.05$) high level ofK (1.91Cmol/+kg), available P (51.45 ppm), Total N (0.19%) and OC (2.19%), in combined TR, intercrop sorghum/chickpea with application of MRP+FYM during SRS of 2012 compared to the other treatment combinations.

Keywords: *cropping systems; tillage practices; organic inputs; semi-arid; soil nutrients.*

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Abstract- Low use efficiencies of inorganic fertilizers coupled with their rising costs has diverted attention of farmers towards organic sources. Against this backdrop, a study was conducted in Matuu in Yatta sub-county, Machakos County, to evaluate the influence of tillage practices, cropping systems and organic inputs on soil nutrient status. The study was carried out between October 2012 to February 2013 short rains (SRS) and April-August 2013 long rainy seasons (LRS). ARandomized Complete Block Design with a split-split plot arrangement replicated three times was used where the main plots were the tillage practices (TP): Oxen plough (OP), Tied ridges (TR) and Furrows and Ridges (FR). The split-plots comprised the cropping systems (CS): Mono-cropping (MC), Intercropping (IC), and Crop rotation (CR) while split-split plots were organic inputs: Farmyard manure (FYM), Minjingu Rock Phosphate (MRP), combined MRP and FYM (MRP+FYM) plus the Control. The test crops were sorghum and sweet potatoes (*Impomea batata*) with Dolichos (*Dolichos lablab*) and chickpea (*Cicerarietinum*L.) added either as intercrops or in rotation. Soil samples were taken randomly at 0-30 cm depth at the onset of the experiment and at maturity of test crop for soil (NPK and %OC) analysis. There was a significant ($P \leq 0.05$) high level ofK (1.91Cmol/+kg), available P (51.45 ppm), Total N (0.19%) and OC (2.19%), in combined TR, intercrop sorghum/chickpea with application of MRP+FYM during SRS of 2012 compared to the other treatment combinations. Comparing different organic inputs, tillage practices and cropping systems combined TR, intercrop of sorghum/chickpea and MRP+FYM and FYM increased the soil nutrients status.

Keywords: cropping systems; tillage practices; organic inputs; semi-arid; soil nutrients.

I. Introduction

Low soil fertility and moisture deficits are major constraints to crop production in the semi-arid areas of Kenya. Many interrelated factors, both natural and managerial, lead to soil fertility decline either through leaching, erosion, and crop harvesting (Donovan and Casey, 1998). The low soil fertility is majorly contributed by agriculture intensification particularly in developing countries (Rezig *et al.,* 2012) due to the ever-increasing food demand for the rising population. Unless the nutrients are replenished using organic or mineral fertilizers, partially returned through crop residues or rebuilt more comprehensively through traditional fallow systems that allow restoration of nutrients and reconstruction of soil organic matter, soil nutrient levels will decline continuously. Therefore, the use of species different from the main crop such as legumes contributes to the nutrient balance, which may consequently increase soil fertility level over time. Leguminous species are known for their capacity to fix atmospheric di-nitrogen in association with rhizobia bacteria and hence narrow the C: N ratio, resulting in faster residue decomposition (Aita and Giacomini, 2003) with consequent release of accumulated N, P and K to the soil (Borkert *et al.,*2003).Legume green manures are also efficient at mobilizing P from the soil (Knight and Shirtliffe, 2005) pool through decomposition and release in a labile form that enhances P nutrition of succeeding crops (Cavigelli and Thien, 2003).

Farmers in the Eastern part of Kenya use farmyard manure (FYM) as a cheaper alternative source of plant nutrients as opposed to the more expensive inorganic fertilizers (Gichangi *et al.,* 2007).Farmyard manure acts as an alternative source of fertility enhancement as they release nutrients more slowly and steadily over a period of time and also improve the soil fertility status by activating the soil microbial biomass (Belay *et al.,* 2001; Karuku and Mochoge, 2016).Consequently, inputs from organic sources such as FYM, play a pivotal role in the productivity of many farming systems by providing nutrients through decomposition and substrate for the synthesis of soil organic matter (SOM). SOM has been shown to improve crop growth and yield by supplying nutrients or by modifying soil physical properties (Rees *et al.,* 2000; Karuku et al., 2012&2014) and environment.

Furthermore, SOM acts as a bonding and dispersing agent by increasing inter-particle hydrophobicity and cohesion within aggregates (Mullins 2000; Abiven *et al*., 2009). It is well known that manures are sources of all-necessary macro- and micro-nutrients in available forms, thereby improving the physical, chemical and biological properties of the soil (El-Magd *et al*., 2005; Zhang, 2005). Due to the slow process of decomposition, manures are usually applied at higher rates, relative to that of inorganic fertilizers, to meet crop nutrient requirements and the excess have positive residual effects on the growth and yield of succeeding

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crops (Makinde and Ayoola, 2008). Application of manures to soil similarly provide other potential benefits such as improved fertility and structure, increased soil organic matter buildup and improved water holding capacity (Phan *et al.*, 2002; Blay *et al.*, 2002).In addition tillage practices such as; Tied ridges and Furrows and Ridges may allow rainwater retention on open furrows for longer duration as the water infiltrates into the soil or soil management techniques that favor prolonged rainwater infiltration and retention thus raising the overall soil moisture availability and hence improved crop production in ASALs (Itabari, 2003). This study evaluated the effects of tillage practices, cropping system and organic inputs on soil nutrients N, P, K, and organic carbon in Yatta Sub County.

a) Study Site

The study was carried out in Yatta Sub County, Kenya, coordinates-1.4667°S and 37.8333°E at 944m asl. The sub-county falls under agro-ecological zones IV, classified as semi-arid lands (Jaetzold and Schmidt, 2006). Yatta Sub County comprises a suite of soils that includes Acrisols and Luvisols in association with Ferrallisols (WRB, 2006). In most places, the topsoil is loamy sand to sandy loam, sandy clay to clay with low nutrient availability (Kibunja *et al.,* 2010).

The mean annual temperature vary from 18 to 24°C and the area experiences bimodal rainfall with long rains in early April to May (about 400 mm) and short rains commencing from early October to December (500 mm). Most farmers in the Sub County practice small-scale mixed farming with crops grown ranging frommaize (*Zea mays*), beans (*Phaseolus vulgaris*), pigeon pea (*Cajanus cajan*), green grams (*Vigna radiata*), sorghum (*Sorghum bicolor*), and cowpea (*Vigna unguiculata*) (Macharia, 2004).

Initial soil analysis indicated that the soils at the site were acidic sandy clay, low in fertility, with low amounts of TN, OC and available P (Table 1). This was attributed to farmers' reliance on one continuous cropping systems without application of organic inputs. Smalling *et al.* (1997) stated that continuous cropping of land with little or no nutrient returns, results in their depletion hence decline in soil fertility.

Table 1: Initial soil physical and chemical properties

Soil chemical properties	% OC	% TN	P (ppm)	K (Mol/Kg)	PH H_20	PH $CACL_2$	CEC
	1.86	0.1	26.84	1.91	5	5.63	14.65
Soil physical properties	%Clay	% loam	% sand	Textural class			
	54	22	24	Sand clay			

Farm yard manure used in the study was slightly alkaline at a pH of 8.2,OC of 18.6 %, TN at 2.1 % and P and K contents of 0.4 % and 2.7 %, respectively. The Ca content was 3.4 % (Table 2).

Table 2: Salient properties of FYM used in the study

chemical properties of FYM	% OC	% Total N	% P	% K	% Ca	% Na	PH H_20
	18.6	2.1	0.4	2.7	3.5	0.8	8.2

b) Treatments and Experimental design

The treatments were tillage practices (Oxen plough, Tied ridges and, Furrows and ridges), cropping systems (mono cropping, intercropping, and crop rotation) and organic inputs (farmyard manure, rock phosphate, and combined Farmyard manure and rock phosphate) and control. The experiment was in a Randomized Complete Block Design with split-split plot arrangement. The main plots (150m x 60m) were; tillage practices (Oxen plough, tied ridges and furrows, and ridges). Split plots (10m x 4m) were cropping systems (mono cropping, intercropping, and crop rotation) and split-split plots (2.5m x 1m) were organic inputs (farmyard manure, rock phosphate and combined Farmyard manure and rock phosphate). A control (no organic inputs applied) was also included as a split-split plot. The test crops were sweet potatoes (*ipomeabatatas*lam) and sorghum (*sorghum bicolor l.*) with Dolichos (*Dolichos lablab)* and chickpea (*Cicerarietinum*L.) either as intercrops or in rotation.

c) Field Practices

Land was prepared manually using oxen plough in late September and planted in October short rain of 2012 and April long rain season 2013.Manure was broadcasted at a rate of $5tha^{-1}$, Minjingu rock phosphate (MRP) at $498kgha^{-1}$ equivalent to $60kgP\ ha^{-1}$, thoroughly mixed with the soil before the vines and seeds were placed in the holes. Sweet potatoes (wabolinge variety) were propagated through 30cm long cuttings at a spacing of 90cm between rows and 30cm within rows. Weeding was done 5 weeks after planting and harvesting after 6 months when the leaves turned yellow and dry. The harvesting was done using a sharp hoe to remove all tubers (Mureithi, 2005).Sorghum (serendo variety) was sown at spacing of 75cm by 30cm while

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dolichos and chickpea were planted at a spacing of 30cm within the sorghum and sweet potato rows. Weeding was done after 5 weeks of planting and harvesting after three months when it had reached physiological maturity.

d) Soil sampling and analysis

Soil samples were collected in a transect (in a zigzag manner from one edge of the field) for initial soil analysis. Soil samples were later taken at maturity of sweet potato and sorghum as main crops, at three samples per treatment which were then composited into a single sample and mixed thoroughly. The sample was air-dried by spreading it out in a clean, warm, dry area for two days before being analyzed for N by micro-kjeldahl method as described by Bremner (1996); P by double acid method; K by flame photometry and organic carbon determined following Walkley and Black (1934) as described by Nelson and Sommers (1996). Soil pH-H2O and pH-CaCl2 was determined with a pH meter in a 1:2.5 ratio extract. Electrical conductivity (ECe) was measured on a 1:2.5 ratio extract with an EC meter.

e) Statistical analysis

Data was subjected to general analysis of variance using GenStat statistical software (Payne et al., 2005) version 18. Means were separated using least significant difference at a probability level of 5%.

II. Results Discussion

a) Effects of tillage practice, cropping systems and organic inputs on soil nutrients status

Potassium (K)content was significantly ($P \leq 0.05$) affected by the organic inputs as increased level were recorded with application of MRP + FYM in all tillage practices and cropping systems, compared to the other organic inputs MRP, FYM and their controls. Increased K content was observed under combined oxen plough (OP), sorghum mono cropping with application of MRP+FYM (3.37Cmol+/Kg) and intercropping sweet potato/dolichos (3.08Cmol+/Kg)as compared to other tillage practices, combined furrows and ridges, intercropping sorghum/ dolichos with application MRP+FYM (2.01Cmol+/Kg)and intercropping sweet potato/dolichos (2.14Cmol+/Kg) and tied ridges with intercropping of sorghum/chickpea (1.91Cmol+/Kg) and intercropping of sweet potato /chickpea (2.06Cmol+/Kg).

Increased Kcontent under MRP+FYM application was attributed to the fact that when farmyard manure and Minjingu rock phosphate are mixed, it enhances release of other nutrients such as K through increased microbial activity in the soil. Same applies when FYM was applied. Low K content under Tied ridges (1.91Cmol+/Kg); Furrows and ridges (2.11Cmol+/Kg) compared to OP (2.95Cmol+/Kg) could be attributed to increased soil moisture content leading to loss of the nutrients down the profile due to leaching of K in the upper profile as compared to OP. Under different cropping systems, increased K content was observed under intercrop and crop rotation of both chickpea and dolichos in all tillage practices. This was attributable to the effects of exudates such as H^+ and other organic acids released by the legumes in the rhizosphere and works on the organic materials applied thus mineralizing more nutrients to the soil. Root-secreted chemicals mediate multi-partite interactions in the rhizosphere, where plant roots continually respond to and alter their immediate environment. Increasing evidence suggests that root exudates initiate and modulate dialogue between roots and soil microbes. For example, root exudates serve as signals that initiate symbiosis with rhizobia and my corrhizal fungi. In addition, root exudates maintain and support a highly specific diversity of microbes in the rhizosphere of given particular plant species, thus suggesting a close evolutionary link (Dayakar & Jorge, 2009; Sunita, 2017). Moreover, inclusion of legumes in crop rotations protects the fragile soil surface by restoring the organic matter content and organic fertility of these soils. This would also help to restore the natural fertility of these soils.

Increased potassium level under intercropping and crop rotation of chickpea and dolichos was also reported by Ahmad et al., (2010) who found out that use of green manure especially legumes in a cropping pattern could help restore crop productivity. In addition Aziz *et al*. (2010) reported that manure application significantly increases soil K contents due to increased microbial activity in the soil. Another similar observation was made by Suge *et al.(2011) ,* who found that addition of Organic fertilizers improve soil water holding capacity as well as the CEC and nutrients are released slowly to crop plants thus impacting on nutrients availability. The inclusion in a rotation of cover crops or green manures can also enhance the efficient use of nutrients by plants, mainly owing to the increase in soil microbial population and activity (Watson et al., 2002).

b) Changes in potassium content Cmol+/Kg across the seasons (SRS 2012 and LRS 2013)

Changes in potassium content across the two season was observed with increase during the LRS(3.65Cmol+/Kg) and (3.39 Cmol+/Kg) as compared to the SRS (3.37Cmol+/Kg) and (3.09Cmol+/Kg) under oxen plough in sorghum mono cropping and intercropping of sweet potato/ dolichos with the application of MRP+FYM in sorghum and sweet potato plots respectively (Table 3 and 4).During the LRS of 2013 the soil moisture content increased as a result of prolonged rainfall as opposed to SRS of 2012.Soil moisture content affects the availability of K in soil, greater efficiency of K fertilizer with increasing soil

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moisture since it influence microbial activities responsible for decomposition for release of potassium. Decomposition of organic matter is chiefly carried out by heterotrophic microorganisms. This process is influenced by temperature, moisture and ambient soil conditions leading to the release and cycling of plant nutrients, especially nitrogen (N), potassium and phosphorus (Murphy et al., 2007; Sunita, 2017).

c) Available phosphorous

The soil available P level increased significantly ($P \leq 0.05$) in plots with MRP+FYM compared to other treatments FYM, MRP and control. Accordingly, combined TR, intercropping sweet potato and sorghum/dolichos with application of MRP +FYM had highest P levels (51.45 ppm and (46.31 ppm), respectively in the SRS of 2012 (Table 5 and 6).Increased available P with application of MRP+FYM was due to the enhanced release from MRP when mixed with FYM since decomposition of FYM releases humic acid which further promote the release of P from the rock. Organic exudates of soil microbes and roots of grain legume crops can mobilize phosphorus from unavailable soil-P pool and increase its availability for P inefficient plant species grown in inter-cropping or crop rotation. Legume crops adopt different strategies such as development of cluster roots, exudation of carboxylates, protons and acid phosphatase to render the P available from inorganic and organic P sources.

Table 3: Effects of tillage practice, cropping systems and organic inputs on soil potassium Cmol+/Kg sorghum based plots during SRS of 2012 and LRS of 2013

			SRS 2012				LRS 2013			
TP	CS	CROP	CTRL	FYM	MRP	MRP+FYM	CTRL	FYM	MRP	MRP+FYM
FR	Crop rotation	CP-SOR	1.29^{bc}	1.4^{de}	1.48^{def}	1.67^{gh}	1.4^{bc}	1.52^{de}	1.6^{def}	1.81^{gh}
	crop rotation	DOL-SOR	1.08^{a}	1.13^{a}	1.18^{ab}	1.34^{cd}	1.17^{a}	1.22^{a}	1.28^{ab}	1.45^{cd}
	inter cropping	SOR/DOL	1.62^{gh}	1.7^{ghi}	1.77^{ghi}	2.01^{k}	1.75^{gh}	1.84^{ghi}	1.92^{ghi}	2.18^{k}
	inter cropping	SOR/CP	1.55^{defg}	1.72^{gh}i	1.87^{ghi}	2.11^{k}	1.68^{defg}	1.84^{ghi}	1.92^{ghi}	l2.18^{k}
	mono cropping	SOR	1.19^{ab}	1.29^{bc}	1.36^{cd}	1.54^{defg}	1.29^{ab}	1.4^{bc}	1.47^{cd}	1.67^{defg}
OP	crop rotation	CP-SOR	2.54^{m}	2.66^{mn}	2.78^{o}	3.15^{q}	2.75^{m}	2.88^{mn}	3.01^{o}	3.41^{q}
	crop rotation	DOL-SOR	2.64^{mn}	2.77^{o}	2.9^{p}	3.28^{qr}	2.86^{mn}	3^{o}	3.14^{p}	3.56^{q}
	inter cropping	SOR/DOL	2.54^{m}	2.66^{mn}	2.78^{o}	3.15^{q}	2.75^{m}	2.88^{mn}	3.01^{o}	3.41^{q}
	inter cropping	SOR/CP	2.37^{lm}	2.49^{m}	2.6^{mn}	2.95^{p}	2.57^{l}	2.69^{m}	2.82^{mn}	3.19^{p}
	mono cropping	SOR	3.08^{q}	3.82^{t}	3.22^{qr}	3.37^{s}	3.33^{q}	4.14^{t}	3.49^{qr}	3.65^{s}
TR	crop rotation	CP-SOR	1.45^{def}	1.58^{defg}	1.66^{gh}	1.88^{ghij}	1.58^{def}	1.71^{defg}	1.8^{gh}	2.04^{ghij}
	crop rotation	DOL-SOR	1.16^{a}	1.26^{bc}	1.33^{cd}	1.51^{def}	1.26^{a}	1.37^{bc}	1.44^{cd}	1.63^{def}
	inter cropping	SOR/DOL	1.33^{cd}	1.44^{de}	1.52^{def}	1.72^{ghi}	1.44^{cd}	1.56^{de}	1.64^{def}	1.86^{ghi}
	inter cropping	SOR/CP	1.47^{def}	1.61^{gh}	1.68^{gh}	1.91^{ghij}	1.6^{def}	1.75^{gh}	1.82^{gh}	2.07^{ghij}
	mono cropping	SOR	1.13^{a}	1.23^{ab}	1.29^{bc}	1.46^{def}	1.22^{a}	1.33^{ab}	1.4^{bc}	1.59^{def}

Legend: SOR-sorghum, DOL-dolichos, CP-chickpea, TP-tillage practice, TR-tied ridges, FR-furrows and ridges, OP-oxen plough, FYM-farm yard -manure, MRP-Minjingu rock phosphate, CTRL-control, LRS-long rain season, SRS-short rain season, CS-cropping system. Under rotation legumes were harvested during the short rain season 2012 whereas sweet potatoes and sorghum were harvested during the long rain season 2013. Means followed by the same letters in the same season in a column are not significantly different at $P \leq 0.05$.

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Table 4: Effects of tillage practice and organic cropping systems on soil potassium Cmol+/Kg sweet potato based plots during SRS of 2012 and LRS of 2013

			SRS 2012				LRS 2013			
TP	CS	CROP	CTRL	FYM	MRP	MRP+FYM	CTRL	FYM	MRP	MRP+FYM
FR	crop rotation	CP-SP	1.58^{h}	1.66^{hi}	1.73^{hij}	1.96^{m}	1.74^{h}	1.82^{hi}	1.91^{hij}	2.16^{m}
	crop rotation	DOL-SP	1.04^{a}	1.09^{b}	1.14^{b}	1.29^{bcd}	1.14^{a}	1.2^{b}	1.25^{b}	1.42^{bcd}
	inter cropping	SP/DOL	1.73^{hij}	1.81^{k}	1.89^{l}	2.14^{o}	1.9^{hij}	1.99^{k}	2.08^{l}	2.36^{o}
	inter cropping	SP/CP	1.13^{b}	1.19^{bc}	1.24^{bcd}	1.41^{ef}	1.25^{b}	1.31^{bc}	1.37^{bcd}	1.55^{ef}
	mono cropping	SP	1.09^{b}	1.18^{bc}	1.24^{bcd}	1.41^{ef}	1.19^{b}	1.3^{bc}	1.37^{bcd}	1.55^{ef}
OP	crop rotation	CP-SP	2.28^{q}	2.38^{r}	2.49^{s}	2.82^{v}	2.5^{q}	2.62^{r}	2.74^{s}	3.11^{v}
	crop rotation	DOL-SP	1.19^{bc}	1.24^{bcd}	1.3^{bcde}	1.47^{efg}	1.31^{bc}	1.37^{bcd}	1.43^{bcde}	1.62^{efg}
	inter cropping	SP/DOL	2.48^{s}	2.6^{t}	2.72^{u}	3.08^{w}	2.73^{s}	2.86^{t}	2.99^{u}	3.39^{w}
	inter cropping	SP/CP	1.29^{bcd}	1.36^{ef}	1.42^{efg}	1.61^{h}	1.42^{bcd}	1.49^{ef}	1.56^{efg}	1.77^{h}
	mono cropping	SP	2.21^{p}	2.75^{u}	2.32^{q}	2.42^{r}	2.43^{p}	3.02^{u}	2.55^{q}	2.67^{r}
TR	crop rotation	CP-SP	1.27^{bcd}	1.38^{ef}	1.45^{efg}	1.65^{hi}	1.4^{bcd}	1.52^{ef}	1.6^{efg}	1.81^{hi}
	crop rotation	DOL-SP	1.02^{a}	1.11^{b}	1.16^{bc}	1.32^{bcde}	1.12^{a}	1.22^{b}	1.28^{bc}	1.45^{bcde}
	inter cropping	SP/DOL	1.57^{h}	1.71^{hij}	1.8^{k}	2.04^{n}	1.73^{h}	1.88^{hij}	1.98^{k}	2.24^{n}
	inter cropping	SP/CP	1.58^{h}	1.73^{hij}	1.81^{k}	2.06^{n}	1.75^{h}	1.89^{hij}	1.99^{k}	2.26^{n}
	mono cropping	SP	1.03^{a}	1.12^{b}	1.18^{bc}	1.34^{bcde}	1.13^{a}	1.23^{b}	1.3^{bc}	1.47^{bcde}

Legend: SP-sweet potato, DOL-dolichos, CP-chickpea, TP-tillage practice, TR-tied ridges, FR-furrows and ridges, OP-oxen plough, FYM-farm yard -manure, MRP-Minjingu rock phosphate, CTRL-control, LRS-long rain season, SRS-short rain season, CS-cropping system.. Means followed by the same letters in the same season in a column are not significantly different at P ≤ 005.

Table 5: Effects of tillage practice and organic inputs on soil available phosphorous sorghum based plots during SRS of 2012 and LRS of 2013

TP	CS	CROPS	SRS 2012				LRS 2013			
			CTRL	FYM	MRP	MRP+FYM	CTRL	FYM	MRP	MRP+FYM
FR	crop rotation	CP-SOR	27.1^{g}	29.04^{j}	30.25^{k}	34.28^{p}	30.97^{g}	33.19^{j}	34.57^{k}	39.18^{p}
	crop rotation	DOL-SOR	30.78^{l}	32.98^{lmn}	34.35^{p}	38.93^{s}	35.18^{l}	37.69^{lmn}	39.26^{p}	44.5^{s}
	inter cropping	SOR/DOL	34.75^{p}	37.23^{r}	38.78^{s}	43.95^{x}	39.71^{p}	42.55^{r}	44.32^{s}	50.23^{x}
	inter cropping	SOR/CP	38.14^{s}	40.86^{v}	42.56^{v}	48.24^{y}	43.58^{s}	46.7^{v}	48.64^{v}	55.13^{y}
	mono cropping	SOR	25.17^{ef}	26.96^{g}	31.83^{lm}	28.09^{ghi}	28.76^{ef}	30.82^{g}	36.38^{lm}	32.1^{ghi}
OP	crop rotation	CP-SOR	21.68^{b}	23.23^{d}	24.2^{e}	27.42^{gh}	24.78^{b}	26.55^{d}	27.66^{e}	31.34^{gh}
	crop rotation	DOL-SOR	24.62^{e}	26.38^{g}	27.48^{gh}	31.15^{l}	28.14^{e}	30.15^{g}	31.41^{gh}	35.6^{l}
	inter cropping	SOR/DOL	27.8^{gh}	29.78^{k}	31.03^{l}	35.16^{q}	31.77^{gh}	34.04^{k}	35.46^{l}	40.19^{q}
	inter cropping	SOR/CP	30.51^{k}	32.69^{lmn}	34.05p	38.59^{s}	34.87^{k}	37.36^{lmn}	38.91^{p}	44.1^{s}
	mono cropping	SOR	20.13^{a}	22.47^{c}	21.57^{b}	25.47^{ef}	23.01^{a}	25.68^{c}	24.65^{b}	29.1^{ef}
TR	crop rotation	CP-SOR	28.91^{j}	30.97^{l}	32.26^{lm}	36.57^{r}	33.04^{j}	35.4^{l}	36.87^{lm}	41.79^{r}
	crop rotation	DOL-SOR	32.83^{lmn}	35.18^{q}	36.64^{r}	41.53^{v}	37.52^{lmn}	40.2^{q}	41.88^{r}	47.46^{v}
	inter cropping	SOR/DOL	37.07^{r}	39.71^{t}	41.37^{v}	46.88^{y}	42.36^{r}	45.39^{t}	47.28^{v}	53.58^{y}
	inter cropping	SOR/CP	40.68^{u}	43.58^{w}	45.4^{x}	51.45^{z}	46.49^{u}	49.81^{w}	51.89^{x}	58.8^{z}
	mono cropping	SOR	26.84^{g}	28.76^{j}	33.95^{o}	29.96^{k}	30.68^{g}	32.87^{j}	38.81^{o}	34.24^{k}

Legend: SOR-sorghum, DOL-dolichos, CP-chickpea, TP-tillage practice, TR-tied ridges, FR-furrows and ridges, OP-oxen plough, FYM-farm yard -manure, MRP-Minjingu rock phosphate, CTRL-control, LRS-long rain season, SRS-short rain season, CS-cropping system.. Means followed by the same letters in the same season in a column are not significantly different at P ≤ 0.05.

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Table 6: Effects of tillage practice and organic inputs on soil available phosphorous sweet potato based plots during Short Rain Season 2012 and Long Rain Season 2013

			SRS 2012				LRS 2013			
TP	CS	CROPS	CTRL	FYM	MRP	MRP+FYM	CTRL	FYM	MRP	MRP+FYM
FR	crop rotation	CP-SP	24.39^{f}	26.13^{fghi}	27.22^{fghij}	30.85^{m}	27.88^{f}	29.87^{fghi}	31.11^{fghij}	35.26^{m}
	crop rotation	DOL-SP	27.7^{fghij}	29.68^{jkl}	30.92^{m}	35.04^{p}	31.66^{fghij}	33.92^{jkl}	35.33^{m}	40.05^{p}
	inter cropping	SP/DOL	31.27^{m}	33.51^{o}	34.9^{p}	39.56^{u}	35.74^{m}	38.29^{o}	39.89^{p}	45.21^{u}
	inter cropping	SP/CP	34.32^{p}	36.77^{r}	38.31^{t}	43.41^{x}	39.23^{p}	42.03^{r}	43.78^{t}	49.62^{x}
	mono cropping	SP	22.65^{de}	24.27^{f}	28.65^{jkl}	25.28^{fgh}	25.89^{de}	27.73^{f}	32.74^{jkl}	28.89^{fgh}
OP	crop rotation	CP-SP	19.51^{b}	20.91^{bc}	21.78^{d}	24.68^{fg}	22.3^{b}	23.89^{bc}	24.89^{d}	28.21^{fg}
	crop rotation	DOL-SP	22.16^{d}	23.74f	24.73^{fg}	28.03^{jk}	25.33^{d}	27.14^{f}	28.27^{fg}	32.04^{jk}
	inter cropping	SP/DOL	25.02^{fg}	26.81^{fghi}	27.92^{jk}	31.65^{mn}	28.59^{fg}	30.64^{fghi}	31.91^{jk}	36.17^{mn}
	inter cropping	SP/CP	27.46^{fghij}	29.42^{jkl}	30.65^{m}	34.73^{p}	31.38^{fghij}	33.62^{jkl}	35.02^{m}	39.69^{p}
	mono cropping	SP	18.12^{a}	20.22^{bc}	19.41^{b}	22.92^{de}	20.71a	23.11^{bc}	22.19^{b}	26.19^{de}
TR	crop rotation	CP-SP	26.02^{fgh}	27.88^{jk}	29.04^{jkl}	32.91^{o}	$29.73f^{gh}$	31.86^{jk}	33.19^{jkl}	37.61^{o}
	crop rotation	DOL-SP	29.55^{jkl}	31.66^{mn}	32.98^{o}	37.38^{rs}	33.77^{jkl}	36.18^{mn}	37.69^{o}	42.72^{rs}
	inter cropping	SP/DOL	33.36^{o}	35.74^{pq}	37.23^{r}	42.2^{w}	38.12^{o}	40.85^{pq}	42.55^{r}	48.22^{w}
	inter cropping	SP/CP	36.61^{r}	39.23^{u}	40.86^{v}	46.31^{y}	41.84^{r}	44.83^{u}	46.7^{v}	52.92^{y}
	mono cropping	SP	24.16^{f}	25.89^{fgh}	30.56^{m}	26.96^{fghij}	27.61^{f}	29.58^{fgh}	34.92^{m}	30.82^{fghij}

Legend: SP-sweet potato, DOL-dolichos, CP-chickpea, TP-tillage practice, TR-tied ridges, FR-furrows and ridges, OP-oxen plough, FYM-farm yard -manure, MRP-Minjingu rock phosphate, CTRL-control, LRS-long rain season, SRS-short rain season, CS-cropping system.. Means followed by the same letters in the same season in a column are not significantly different at $P \leq 0.05$.

Thus, inter-cropping or crop rotation of cereal crops with such legumes that have improved mechanisms to gain access to this fixed P will contribute toward more sustainable agriculture (Sunita, 2017).In addition it implies that MRP underwent considerable dissolution leading to release of Pin the MRP applied. Addition of FYM results into an increased microorganism decomposition rates and thus release phosphorous into the soil. Organic manures after decomposition may also provide organic acids and increase P-bioavailability after dissolution of MRP when combined with FYM. Sunita (2017) reported similar findings in India. This also conforms to a study by Mengel and Kirk by (2001); Marschner (2011) who noted an increase in P contents with addition of FYM and attributed it to mineralization and increased water holding capacity, thus making P readily available to crops. A study by KARI (1996) stated that application of FYM affect available P content considerably. In addition FYM increase soil moisture content (Boateng *et al.*, 2006), increase microbial activity and resultant biochemical transformations of P in soil. The added organic manures may lead to mineralization of more recalcitrant P fraction(Nziguheba *et al.*, 1998) as studies conducted by Maerere *et al.* (2001) and Odedina *et al.* (2011) have also reported.

There was a significant difference ($p \leq 0.05$) across the tillage practices with increased available P content under Tied ridges (51.45 ppm) compared to Furrows and ridges (48.24 ppm)and Oxen plough (38.59 ppm) under intercropping sorghum/chickpea and with the application of MRP+FYM during the SRS of 2012.The increased P under Tied ridges and Furrows and ridges was attributed to the increased soil moisture content harvested under Tied ridges and Furrows and ridges resulting in reduced runoff hence less soil loss by erosion and hence reduced P losses. P in soil is less mobile and most losses are due to soil erosion. Kaushik and Gautam(1997) found out that increased soil water retention reduces nutrients losses through erosion. Oxen ploughed plots may have had lower P due to increased loss through erosion and leaching. Kaumbutho and Simalenga (1999) documented that use of the oxen plough tillage practice could increase erosion due to the inappropriate width adjustment on the plough which led to formation of plough furrows acceleration the rate of rill erosion, especially in sloping lands causing nutrients losses.

There was also a significant difference ($p \leq 0.05$) across all the cropping systems with increased P content under the intercropping of chickpea (51.45 ppm) and dolichos (46.88 ppm) in Tied ridges with the application of MRP+FYM during SRS 0f 2012.This was due to enhanced release of the nutrients from the organic inputs as presence the legumes enhanced release, fixation of nutrients and increased biological activity.

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This is supported by the findings of Suge *et al*. (2011) who attributed increased available P to crop rotation, Larkin (2008) indicated that crop rotation help in pests and diseases control thus increasing soil biological activity while Christen and Sieling (1995) observed increased water use efficiency which in turn increased P content in the soil under crop rotation. This conforms to a study by Kamkar and Damghani (2009) who found out that crop rotation along with increasing soil organic matter increased biodiversity and soil biological community.

d) Changes in phosphorous content ppmacross the season (SRS 2012 and LRS 2013)

Changes in P content across the two season indicated an increase during the LRS (58.8 ppm) and (52.92 ppm) compared to the SRS (51.45 ppm) and (46.31 ppm) under OP in intercropping of sorghum/ chickpea and sweet potato/ chickpea with the application of MRP+FYM in sorghum and sweet potato plots, respectively (Table 7 and 8).The higher amounts of soil available P in the LRS 2013 than SRS 2012 was attributed to the residual effects of the organic inputs applied (MRP, MRP+FYM and FYM). According to Rowell(1994), the rapid adsorption of P onto soil particle is followed by a slower conversion into less available forms including mineral phosphates, thus P in the MPR and most phosphate fertilizers is available in the first season after application but the rest remains over long periods of time hence their residual effects.

e) Total Nitrogen

Total N increased significantly ($P \leq 0.05$) through application of FYM in all the tillage practices and cropping systems compared to other treatments. Significant ($P \leq 0.05$) increased % TN (0.19) was recorded under FYM with the intercrop of dolichos/sorghum in Furrows and ridges (Table 7 and 8).The increase in soil TN after FYM application was due to addition of N by decomposing FYM. These results conformsto the findings of Thamaraiselvi *et al*. (2012) who reported an increases in soil TN with FYM application. Nyambati (2000) also reported that MRP and organics (FYM) combinations provide cheap N sources. Also solubilisation of MRP through formation of favorable acid environments that result when organics are in contact with MRP decompose in soils releasing N to the soil.

Percent TN content increased significantly ($p \leq 0.05$) across cropping system with crop rotation dolichos/sorghum at 0.21% and intercrop sorghum/chickpea at 0.19% under Tied ridges and application of FYM (Table 7). This same trend was observed under Furrows and ridges (0.19% and 0.17%) and OP (0.15% and 0.13%) under crop rotation of dolichos/sorghum and intercrop though the content was lower compared to sorghum planted plots. The increased in TN under dolichos intercrop and rotation was attributed to the legumes ability to fix Nitrogen and the amount obtained from the legumes residues which led to increased soil organic matter (SOM) as opposed to the mono-cropping. Aita and Giacomini, (2003) observed that leguminous species have capacity to fix atmospheric nitrogen and narrow the C/N ratio, resulting in faster residue decomposition and consequent release of accumulated N and other nutrients such as P and K, to the soil. Crop rotations usually increase organic matter and prompt changes in N sources, affecting their availability to plants and, as a consequence, the N efficiency is greater when a crop rotation is adopted (Montemurro and Maiorana, 2008). In this study, it was observed that ridges and furrows enhanced infiltration thus reducing runoff and consequently prevented nutrient losses, a fact consistent with FAO (1993). The lower TN content in OP compared to ridges & furrows and Tied ridges was attributed to higher soil erosion and runoff (Kaumbutho and Simalenga, 1999) leading to their loss.

f) Changes in Total Nitrogen across the season

Changes in % TN across the two season was observed to increase during the LRS at 0.23&0.21% compared to SRS at 0.19&0.19% under Tied ridges of intercropped sorghum/ chickpea and crop rotation of dolichos/sweet potato with the application of MRP+FYM in sorghum and sweet potato plots, respectively (Table 7and 8).This implies that TN increased with increased soil moisture during the LRS of 2013 hence mineralization was dictated by soil moisture content. The study there fore show a correlation between soil moisture and soil N mineralization, which agree with previous studies (Li et al. 1995; Zhou and Ouyang, 2001).

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Table 7: Effects of tillage practices and organic cropping systems on soil total N on sorghum based plots during SRS of 2012 and LRS of 2013

			SRS-2012				LRS-2013			
TP	CS	CROPS	CTRL	FYM	MRP	MRP+FYM	CTRL	FYM	MRP	MRP+FYM
FR	crop rotation	CP-SOR	0.1^{c}	0.13^{f}	0.1^{c}	0.11^{d}	0.1^{d}	0.14^{h}	0.11^{e}	0.12^{f}
	crop rotation	DOL-SOR	0.15^{h}	0.19^{l}	0.16^{i}	0.16^{i}	0.16^{j}	0.2^{n}	0.17^{k}	0.18^{l}
	inter cropping	SOR/DOL	0.09^{b}	0.12^{e}	0.09^{b}	0.1^{c}	0.09^{c}	0.13^{g}	0.1^{d}	0.11^{e}
	inter cropping	SOR/CP	0.13^{f}	0.17^{j}	0.14^{g}	0.15^{h}	0.14^{h}	0.18^{l}	0.15^{i}	0.16^{j}
	mono cropping	SOR	0.09^{b}	0.11^{d}	0.12^{e}	0.15^{h}	0.1^{d}	0.12^{f}	0.13^{g}	0.16^{j}
OP	crop rotation	CP-SOR	0.08^{a}	0.11^{d}	0.08^{a}	0.09^{b}	0.08^{b}	0.12^{f}	0.09^{c}	0.1^{d}
	crop rotation	DOL-SOR	0.12^{e}	0.15^{h}	0.12^{e}	0.13^{f}	0.13^{g}	0.16^{j}	0.14^{h}	0.14^{h}
	inter cropping	SOR/DOL	0.07^{a}	0.1^{c}	0.07^{a}	0.08^{a}	0.07^{a}	0.11^{e}	0.08^{b}	0.09^{c}
	inter cropping	SOR/CP	0.1^{c}	0.13^{f}	0.1^{c}	0.11^{d}	0.11e	0.14^{h}	0.12^{f}	0.12^{f}
	mono cropping	SOR	0.08^{a}	0.12^{e}	0.09^{b}	0.09^{b}	0.08^{b}	0.13^{g}	0.09^{c}	0.1^{d}
TR	crop rotation	CP-SOR	0.11^{d}	0.15^{h}	0.11^{d}	0.13^{f}	0.12^{f}	0.16^{j}	0.12^{f}	0.14^{h}
	crop rotation	DOL-SOR	0.16^{i}	0.21^{m}	0.17^{j}	0.18^{k}	0.18^{l}	0.23^{o}	0.19^{m}	0.2^{n}
	inter cropping	SOR/DOL	0.1^{c}	0.14^{g}	0.1^{c}	0.12^{e}	0.12^{f}	0.16^{j}	0.12^{f}	0.14^{h}
	inter cropping	SOR/CP	0.14^{g}	0.19^{l}	0.15^{h}	0.16^{i}	0.18^{l}	0.23^{o}	0.19^{m}	0.2^{n}
	mono cropping	SOR	0.11^{d}	0.12^{e}	0.13^{f}	0.16^{i}	0.11^{e}	0.13^{g}	0.14^{h}	0.18^{l}

Legend: SOR-sorghum, DOL-dolichos, CP-chickpea, TP-tillage practice, TR-tied ridges, FR-furrows and ridges, OI-Organic Inputs OP-oxen plough, FYM-farm yard -manure, MRP-Minjingu rock phosphate, CTRL-control, LRS-long rain season, SRS-short rain season, CS-cropping system.. Means followed by the same letters in the same season in a column are not significantly different at $P \leq 0.05$.

Table 8: Effects of tillage practices and organic cropping systems on soil total N sweet potato based plots during SRS of 2012 and LRS of 2013

TP	CS		SRS 2012				LRS 2013			
			CTRL	FYM	MRP	MRP+FYM	CTRL	FYM	MRP	MRP+FYM
FR	crop rotation	CP-SP	0.08^{c}	0.12^{g}	0.09^{d}	0.1^{e}	0.09^{c}	0.13^{g}	0.09^{c}	0.11^{e}
	crop rotation	DOL-SP	0.13^{h}	0.17^{l}	0.14^{i}	0.15^{j}	0.14^{h}	0.19^{m}	0.15^{i}	0.16^{j}
	inter cropping	SP/DOL	0.07^{b}	0.11^{f}	0.08^{c}	0.09^{d}	0.08^{b}	0.12^{f}	0.08^{b}	0.1^{d}
	inter cropping	SP/CP	0.11^{f}	0.15^{j}	0.12^{g}	0.13^{h}	0.12^{f}	0.17^{k}	0.13^{g}	0.14^{h}
	mono cropping	SP	0.08^{c}	0.09^{d}	0.1^{e}	0.13^{h}	0.09^{c}	0.1^{d}	0.11^{e}	0.14^{h}
OP	crop rotation	CP-SP	0.07^{b}	0.11^{k}	0.08^{c}	0.09^{d}	0.08^{b}	0.12^{f}	0.09^{c}	0.1d
	crop rotation	DOL-SP	0.12^{g}	0.16^{k}	0.13^{h}	0.14^{i}	0.13^{g}	0.18^{l}	0.14^{h}	0.15^{i}
	inter cropping	SP/DOL	0.06^{a}	0.1^{e}	0.07^{b}	0.08^{c}	0.07^{g}	0.11^{e}	0.08^{b}	0.09^{c}
	inter cropping	SP/CP	0.1^{e}	0.14^{j}	0.11^{f}	0.12^{g}	0.11^{e}	0.16^{j}	0.12^{f}	0.13^{g}
	mono cropping	SP	0.07^{b}	0.12^{g}	0.08^{c}	0.09^{d}	0.08^{b}	0.13^{g}	0.09^{c}	0.1^{d}
TR	crop rotation	CP-SP	0.09^{d}	0.13^{h}	0.09^{d}	0.11^{f}	0.1^{d}	0.14^{h}	0.1^{d}	0.12^{f}
	crop rotation	DOL-SP	0.14^{i}	0.19^{m}	0.15^{j}	0.16^{k}	0.16^{j}	0.21^{n}	0.17^{k}	0.18^{l}
	inter cropping	SP/DOL	0.08^{c}	0.12^{g}	0.08^{c}	0.1^{e}	0.09^{c}	0.13^{g}	0.09^{c}	0.11^{e}
	inter cropping	SP/CP	0.12^{g}	0.17^{l}	0.13^{h}	0.14^{i}	0.14^{h}	0.19^{m}	0.15^{i}	0.16^{j}
	mono cropping	SP	0.09^{d}	0.1^{e}	0.11^{f}	0.14^{i}	0.09^{c}	0.16^{j}	0.12^{r}	0.11^{e}

Legend: SP-sweet potato, DOL-dolichos, CP-chickpea, TP-tillage practice, TR-tied ridges, FR-furrows and ridges, OI-Organic Inputs, OP-oxen plough, FYM-farm yard -manure, MRP-Minjingu rock phosphate, CTRL-control, LRS-long rain season, SRS-short rain season, CS-cropping system.. Means followed by the same letters in the same season in column are not significantly different at $P \leq 0.05$.

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g) Organic Carbon

Thelevel of organic carbon increased significantly (P≤0.05) across all cropping system and tillage practices compared to initial soil analysis where FYM and MRP +FYM were added. An increase % OC (2.45) and (3.15) was observed in combined OP, intercrop of sorghum/chickpea and dolichos/sweet potato rotations, respectively where FYM was applied (Table 9 and 10). This was due to high carbon content present in applied FYM as opposed to MRP application alone plus additional residue from legumes that further raised the carbon content.

Across the cropping systems increased % OC was observed under sorghum/dolichos intercropping (2.45%), then rotation of sorghum/chickpea (2.26%) and rotation of sorghum/ dolichos(2.19%) under oxen plough with the application of FYM. Cover crops are generally grown to provide soil cover thus preventing soil erosion by wind and rainwater, which increases organic matter content in the long run (Karuku et al., 2014; Karuku, 2018). Komatsuzaki(2004)indicated that cover crop utilization is a technique that limits nutrient leaching, scavenging the soil residual N and making it available for subsequent cultivation.

Among the three tillage practices, a significant difference (p≤0.05) was observed with improved % OC under OP followed by furrows and ridges though under different cropping systems and application of FYM. The observed %OC level conform to the study by Bayu *et al*. (2006) who noted that FYM application increased soil SOC content by up to 67% over the control. The crop residues from the legumes further act as manures thus increasing % OC and other nutrients. This agrees Knight and Shirtliffe, (2005) where legume green manure increased benefits such as atmospheric N_2fixation and P mobilization from the soil, facts also observed in this with study.

h) Changes in % organic carbon across the season (SRS 2012 and LRS 2013)

Data on % OC changes across seasons indicate an increase during the LRS (2.28%) and (2.27%) compared to the SRS (2.1 %) and (2.51%) under Tied ridges with intercropping sorghum/ dolichos and intercropping sweet potato/ dolichos applied with MRP+FYM in sorghum and sweet potato plots, respectively (Table 8 and 9).The higher % OC observed during LRS is attributed to higher biomass production, which upon decomposition releases CO_2 thus raising carbon levels. Devi *et al*. (2006, 2009) in earlier studies had reported that high rate of CO_2 release during the LRS could be due to a congenial environment for microorganisms dwelling in the soil decomposing organic matter. The low % OC in the SRS seen in the study is attributed to low soil moisture content, temperature and relative humidity, thereby inhibiting the microbial activity (Devi *et al*., 2006; Kosugi *et al.*, 2007). Ginting *et al.* (2003), for example, found out that4 years after the last application of FYM there sidual effects resulted in 20 to 40% higher soil microbial biomass C.

III. Conclusions

Soil organic inputs, MPR and FYM are viable alternatives to the expensive inorganic fertilizers for improving the soil nutrient status in Matuu, Yatta sub County. Combined TR, intercropping of sorghum and sweet potato with dolichos and with application of MRP +FYM significantly increased soil K and P whereas combined TR, intercropping of dolichos with sorghum and sweet potatoes and with application of FYM led to an increase in soil % OC and TN. Moreover, the MRP, FYM are locally available, thus making it an ideal source of nutrients for smallholders economically.

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Table 9: Effects of tillage practices and organic cropping systems on % soil Carbon sorghum based plots during SRS of 2012 and LRS of 2013

			Organic Inputs-SRS 2012				Organic Inputs -LRS 2013			
TP	CS		CTRL	MRP+FYM	MRP	FYM	CTRL	MRP+FYM	MRP	FYM
FR	crop rotation	CP-SOR	1.2^{a}	1.29^{b}	1.34^{bc}	1.52^{de}	1.74^{m}	1.87^{o}	1.94^{opq}	2.2^{tu}
	crop rotation	DOL-SOR	$1.51d^{e}$	1.62^{f}	1.69^{g}	1.91^{ghijk}	1.35^{fg}	1.45^{hi}	1.51^{hij}	1.71^{m}
	inter cropping	SOR/DOL	1.74^{g}	1.87^{ghij}	1.95^{ghijkl}	2.21^{p}	1.9^{op}	2.03^{r}	2.12^{t}	2.4^{w}
	inter cropping	SOR/CP	1.82^{ghi}	1.95^{ghijkl}	2.03^{lmn}	2.3^{pqr}	1.47^{hi}	1.58^{k}	1.64^{l}	1.86^{o}
	mono cropping	SOR	1.93^{ghijkl}	2.06^{lmn}	2.14^{p}	2.43^{s}	1.16^{cde}	1.25^{f}	1.3^{fg}	1.47^{hi}
OP	crop rotation	CP-SOR	1.78^{gh}	1.91^{ghijk}	1.99^{lm}	2.26^{pq}	2.06^{s}	2.21^{tu}	2.3^{tuv}	2.61^{y}
	crop rotation	DOL-SOR	2.52^{t}	2.7^{u}	2.81^{v}	2.19^{p}	0.89^{a}	0.95^{b}	0.99^{b}	1.12^{cd}
	inter cropping	SOR/DOL	1.94^{ghijkl}	2.08^{lmn}	2.16^{p}	2.45^{s}	2.25^{tuv}	2.41^{w}	2.51^{x}	2.84^{z}
	inter cropping	SOR/CP	0.97^{b}	1.04^{c}	1.08^{cd}	1.23^{f}	1.63^{f}	1.74^{g}	1.82^{ghi}	2.06^{lmn}
	mono cropping	SOR	1.7^{m}	2.16^{t}	1.83^{o}	1.9^{op}	2.67^{y}	2.38^{w}	2.87^{w}	2.98^{x}
TR	crop rotation	CP-SOR	1.47^{d}	1.52^{de}	1.6^{f}	1.82^{ghi}	1.29^{fg}	1.33^{fg}	1.4^{h}	1.59^{k}
	crop rotation	DOL-SOR	1.17^{a}	1.21^{a}	1.27^{b}	1.44^{d}	1.02^{c}	1.06^{c}	1.11^{cd}	1.26^{f}
	inter cropping	SOR/DOL	1.7^{g}	1.76^{gh}	1.85^{ghij}	2.1^{lmno}	1.85^{o}	1.91^{op}	2.01^{r}	2.28^{tuv}
	inter cropping	SOR/CP	1.77^{gh}	1.83^{ghi}	1.93^{ghijk}	2.19^{p}	1.45^{hi}	1.48^{hij}	1.56^{k}	1.77^{mn}
	mono cropping	SOR	1.88^{ghij}	1.95^{ghijkl}	2.05^{lmn}	2.33^{pqr}	1.13^{cd}	1.17^{cde}	1.23^{f}	1.4^{h}

Legend: SOR-sorghum, DOL-dolichos, CP-chickpea, TP-tillage practice, TR-tied ridges, FR-furrows and ridges, OP-oxen plough, FYM-farm yard -manure, MRP-Minjingu rock phosphate, CTRL-control, LRS-long rain season, SRS-short rain season, CS-cropping system.. Means followed by the same letters in the same season in a column are not significantly different at $P \leq 0.05$.

Table 10: Effects of tillage practices and organic cropping systems on % soil Carbon sweet potato based plots during SRS of 2012 and LRS of 2013

			Organic Inputs-SRS 2012				Organic Inputs-LRS 2013			
TP	CS		CTRL	MRP+ FYM	MRP	FYM	CTRL	MRP+ FYM	MRP	FYM
FR	crop rotation	CP-SP	1.3^{a}	1.39^{b}	1.45^{bc}	1.65^{de}	1.91^{m}	2.05^{o}	2.14^{opq}	2.43^{tu}
	crop rotation	DOL-SP	1.64^{de}	1.75^{f}	1.83^{g}	2.07^{ghijk}	1.48^{fg}	1.59^{hi}	1.66^{hij}	1.88^{m}
	inter cropping	SP/DOL	1.89^{g}	2.02^{ghij}	2.11^{ghijkl}	2.39^{p}	2.09^{op}	2.24^{r}	2.33^{t}	2.64^{w}
	inter cropping	SP/CP	1.97^{ghi}	2.11^{ghijkl}	2.2^{lmn}	2.5^{pqr}	1.62^{hi}	1.74^{k}	1.81^{l}	2.05^{o}
	mono cropping	SP	2.1^{ghijkl}	2.25^{lmn}	2.34^{p}	2.66^{s}	1.28^{cde}	1.37^{f}	1.43^{fg}	1.62^{hi}
OP	crop rotation	CP-SP	1.93^{gh}	2.07^{ghijk}	2.16^{lm}	2.44^{pq}	2.26^{s}	2.42^{tu}	2.53^{tuv}	2.87^{y}
	crop rotation	DOL-SP	2.73^{t}	2.92^{u}	3.05^{v}	3.15^{y}	0.98^{a}	1.05^{b}	1.09^{b}	1.24^{cd}
	inter cropping	SP/DOL	2.11^{ghijkl}	2.26^{lmn}	2.35^{p}	2.67^{s}	2.47^{tuv}	2.65^{w}	2.76^{x}	3.13^{z}
	inter cropping	SP/CP	1.76^{f}	1.89^{g}	1.97^{ghi}	2.23^{lmn}	1.06^{b}	1.14^{c}	1.19^{cd}	1.35^{f}
	mono cropping	SP	1.87^{m}	2.37^{t}	2.01^{o}	2.09^{op}	2.89^{u}	3.66^{z}	3.1^{w}	3.23^{x}
TR	crop rotation	CP-SP	1.59^{d}	1.65^{de}	1.74^{f}	1.97^{ghi}	1.41^{fg}	1.47^{fg}	1.54^{h}	1.75^{k}
	crop rotation	DOL-SP	1.27^{a}	1.31^{a}	1.38^{b}	1.56^{d}	1.12^{c}	1.16^{c}	1.23^{cd}	1.39^{f}
	inter cropping	SP/DOL	1.84^{g}	1.9^{gh}	2^{ghij}	2.27^{lmno}	2.03^{o}	2.1^{op}	2.22^{r}	2.51^{tuv}
	inter cropping	SP/CP	1.92^{gh}	1.99^{ghi}	2.09^{ghijk}	2.37^{p}	1.57^{h}	1.63^{hij}	1.72^{k}	1.95^{mn}
	mono cropping	SP	2.04^{ghij}	2.11^{ghijkl}	2.23^{lmn}	2.52^{pqr}	1.24^{cd}	1.29^{cde}	1.36^{f}	1.54^{h}

Legend: SP-sweet potato, DOL-dolichos, CP-chickpea, TP-tillage practice, TR-tied ridges, FR-furrows and ridges, OP-oxen plough, FYM-farm yard -manure, MRP-Minjingu rock phosphate, CTRL-control, LRS-long rain season, SRS-short rain season, CS-cropping system.. Means followed by the same letters in the same season in a column are not significantly different at $P \leq 005$.

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Review on Efficacy of Garlic and Onion on Performances, Blood Profile and Health Status of Broiler Chickens

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Abstract- This seminar aimed to review the use of herbal growth promoting factor in poultry production which is acceptable among chicken producers to enhance productivity and control diseases. In poultry production, many alternatives have been investigated to replace antibiotics without any loss of productivity or negative influence on health. One possible way to solve this problem is searching of different plants which have positive influences on growth performance, carcass quality and cholesterol content of the blood without any residual effect on consumers. Garlic and onion are among the most popular plants widely used on the world. In farm animal's different research had been reported on efficacy of onion and garlic as best alternatives of antibiotics in decreasing blood cholesterol, high density lipid and triglyceride, enhancing growth performances, due to, antimicrobial properties of both plants. Garlic and onion contain active ingredients, which have an ability to alter broiler performances. Being the case, Garlic and onion can replace one of the most promising alternatives to antibiotic. However, report of many outers, on dose and efficacy of both plants were not consistent. Therefore, future work will be expected to get accurate result on appropriate dose and rate of effects on broiler.

Keywords: *onion, garlic, allicin, cholesterol, growth performance.*

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Abstract- This seminar aimed to review the use of herbal growth promoting factor in poultry production which is acceptable among chicken producers to enhance productivity and control diseases. In poultry production, many alternatives have been investigated to replace antibiotics without any loss of productivity or negative influence on health. One possible way to solve this problem is searching of different plants which have positive influences on growth performance, carcass quality and cholesterol content of the blood without any residual effect on consumers. Garlic and onion are among the most popular plants widely used on the world. In farm animal's different research had been reported on efficacy of onion and garlic as best alternatives of antibiotics in decreasing blood cholesterol, high density lipid and triglyceride, enhancing growth performances, due to, antimicrobial properties of both plants. Garlic and onion contain active ingredients, which have an ability to alter broiler performances. Being the case, Garlic and onion can replace one of the most promising alternatives to antibiotic. However, report of many outers, on dose and efficacy of both plants were not consistent. Therefore, future work will be expected to get accurate result on appropriate dose and rate of effects on broiler.

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I. Introduction

The use of phytobiotic as alternatives to antibiotic growth promoters in animal diets is still an interesting approach. The herbs and some compound in them could act similar to antibiotics. This compound reduced the growth of some harmful bacteria in the gastrointestinal tract of animals. This can results in a higher efficiency in the feed utilization, higher weight gain and better feed efficiency (Bedford, 2000). Know a days, herbs are considered as best animal growth promoters due to, the controversial effects of antibiotic resistant bacteria and residual effects on the consumers (Nasir and grashhorn,2006; Burgat,1999).

Also, Public bodies such as the American Heart Association gave recommendation concerning consumer's health on possible relationship between dietary fat and coronary heart disease. Phyto-additives are obtained from medicinal plants or plants extract and are being used on a wide range, by humans as well as by animals, including poultry. Recent studies tried to show the effects of phyto additives usage in all farmed animals. Consequently, many researches work focused on searching alternative plants and strategies for animal growth promoters and immune development. Onions and garlic are among the most important plants which have a positive influence on animal growth performance and disease prevention.

Garlic *(Allium sativum)* and onion *(Allium cepa)* are belong to the family Liliaceae and the genus *A. Ilium* (Ebesunun *et al.,* 2007) are among the common medicinal plants used as growth promoters (Ali and Zahran, 2010). Both are contain bioactive substances like, sulphur-containing organic compound known as diakyl polysufides which possess antimicrobial activity, antimicrobial, antioxidant and antihypertensive properties on both humans and animals (Sivam, 2001,Tsao and Yin, 2001; Kumar *et al.2010*). These compounds can improve healthy level off gut through decreasing harmful microbial population (Lee et al, 2003).

There are suggestions that essential oil found in herbs can facilitates digestion; these may be reason that spices and herbs will positively affect food digestion, increases Body weight and other organs by improving the nutrient absorption. Also, as it mentioned by many researchers; using of onion as additives resulted in increasing of feed intake. Being the fact, effect of onion and garlic on animal performance probably is due to antibacterial and antifungal effects originated from some of their compounds. Goodarzi et al. (2013) reported that Using onion in diet can reduce the blood glucose (hypoglycemia), can stimulate nervous system for higher feed intake. Onion contains sulfur organic compounds including S-Methylcysteine sulfoxide and Sallylcysteine suiloxide. These compounds are related to decreasing of blood lipid, liver protein and glucose. Onion could improve growth performance of chicks due to content of organosulphur compounds (An et al., 2015). According to report of (Horton, et.al, 1991; Elagib et al, 2015) Garlic are also similar effects on animal performances; Carcass and organ characteristics of broilers. Spices and their extracts have lipotropic effects, Some of the active components in spices affect lipid metabolism through fatty acid transportation. This can increase the lipid utilization and decrease abdominal fat (Cross et al,

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2007). Know days, diferant works had been reported on positive effect of garlic and onion on growth performance, meat quality, health condition and blood profile of animals. During the last few decades, garlic and onion have received tremendous attention to their wide range of therapeutic properties and great health benefits as functional food (Hasler, 1998; nagourney, 1998).

Onion bulbs have numerous organic sulphur compounds, flavonoids and phenolic acids with proven antibacterial, antioxidant and hypo lipidemic efficacy (Melvin Joe et al., 2009; Srinivasan et al., 2004). The serum cholesterol was significantly decreased by dietary dehydrated onion in experimentally hyper-cholesterolemic rats (Vidyavati et al., 2010). Goodarzi et al. (2013) reported that the beneficial influence of onion extract on the growth performance in meat-type broiler chickens. Supplementing of onion as feed additives in broilers chicken leads the positive influence on body weight, feed conversion efficiency, and average daily feed intake of broilers chicken(Aji et al. 2011; Goodarzi et al. 2013).

Garlic is the herb known for its flavor and pungency and most widely quoted for medicinal properties (hertog, 1998; nagourney, 1998; osman, 2005) *also, it is positive influences in enhancing performances of animals. Brzóska et al., (2015*) stated that garlic extract, given continuously in commercial feed as a feed supplement, caused a significant improvement in the body weight of broilers and their parameters while reducing bird mortality during the rearing period. Therefore, this seminar paper aimed to review effects of garlic and onion in growth performances, lipid metabolism and others blood profile of broiler chicken.

II. Literature Review

a) Back ground of garlic and onion

Onion (*Allium cepa*) and garlic (*Allium sativum*) are belongs to genus *Allium which* have includes about 550 species. A few of these are important as food plants and as drugs in folk medicine, notably onion and garlic are the two most important plants having positive effects on both humans and animals. Bulbs of allium contain flavonoids and sulphur containing compounds; Flavonoids present in the bulbs and leaves of alliums are very effective antioxidants with variable biochemical functions (Hertog and katan, 1998, Wardlay, 1999, evans, et.al, 1995). Garlic and onion has several beneficial actions including antihypertensive, antithrombotic, antibiotic and anti-carcinogenic effects (Vigneshpriya and krishnaveni, 2016).

Allicin and its derivative compounds which found in onion and garlic are the main active substances responsible for the hypolipidemic and hypo cholesterolemic effects in animal body (Osman, 2006). Studies have shown that saponins and flavonoid are able to reduce level of serum cholesterol and arteriosclerosis severity, diabetes (Lanzotti, 2005).

The primary sulphur containing constituents in both plants are the S-alkyl-L-cysteine sulphoxides (ACSOs), such as (a) Methiin and alliin (b) allicin (c) diallyl sulphide (DAS), and diallyl disulphide (DADS). These compounds provide to garlic and onion their characteristic odor and flavor, as well as most of their biological properties. Review of *Bisen and Emerald, 2016 indicated that* Garlic and onion extracts posses many therapeutic properties including antimicrobial, antiviral, antifungal, anti-protozoal, toprotective, cardioprotective, anti-inflammatory, neuro protective, anti-amnesic, anti carcinogenic antimutagenic, antiasthmatic, immuno-modulatory, hypolipidemic, anti-hypertensive, anti-diabetic and antioxidant

b) Effect of garlic and onion on different parameters of chicken

i. *Growth performance*

Using of plants extract as growth promoters was one of the main issues of broilers industries in past two decades hap to now, as soon as the use of antibiotics banned from animal diets due to, its negative effects on consumer health different authors was reported work done on different plants like garlic and onion, their efficacy as alternatives of antibiotic

Ramiah et al. (2014) demonstrated that dietary supplementation of garlic, may improve the growth performance of broilers. other authors reported that the positive effect of garlic supplement in broilers feed diets (Kim et al. 2009; Park, 2008; Ordialez, et al, 2016). The group of the birds fed the diet containing 3% garlic powder attained the highest hot weight, dressed weight, breast weight, fleshed breast weight and fleshed breast percentage(Eligab, 2013)

Toghyani et al (2011) noted that garlic and cinnamon are usually used as flavoring agents, there was the assumption that applying the foregoing spices in broiler diets may leave an influence on meat flavor and tenderness. *Brzóska et al., (2015*) reported that, incorporation of Garlic feed additives at the levels of 1.00, 1.50 and 2.25 ml kg–1 of diet increased the body weight of chickens at 42 days by 1.0, 3.5, and 5.8%, respectively, with control group. in contrast Pourali et al. (2010) reported that garlic supplementation at 0.2, 0.4, 0.6, and 1.0% had negligible influence on growth performance also, Horron et al (1991); Onibi *et al. (*2009) Fadlalla *et al.* (2010), reported that garlic powder had no significant effect on the body weight gain and feed conversion ratio of birds.

ii. *Lipid metabolism*

Onion and garlic are lipotrophic effects containing sulfur organic compounds including *S-Methylcysteine sulfoxide* (SMCS) and *S-allylcysteine*

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suiloxide (SACS) is related to decreasing of blood lipid, liver protein and glucose. It is well known that dietary onion effectively lowers serum cholesterol levels in experimental rats as well as in humans. The decreased levels of blood cholesterol have been reported in rats fed normal diets with onion (Bakhsh and Chungtai, 1985) and high sucrose diet with onion essential oil (Adamu et al., 1982). As well as, in farm animals different research had been conducted on efficacy of onion and garlic as best alternatives of antibiotics in decreasing blood cholesterol, high density lipid and triglyceride due to, antimicrobial properties of both plants .Goodarzi *et al.(2013) demonstrated that* broilers receiving 30 g/kg onion had a significantly higher HDL and lower triglyceride concentrations compared to control groups. Hypocholesterolemic effects with dietary onion may be attributed to decreased cholesterol secretion from liver, or to increased uptake of high density lipoprotein (HDL) uptake into liver. Ordialez et al. (2016) reported that, posetive effect of red onion (Allium-cepa) and lemongrass (Cymbopogon citratus) on lipid oxidation and acceptability of deboned Milkfish (chanos chanos) were assessed.

In contrast, Sklan et al. (1992) reported that found no significant difference in hepatic cholesterol in chicks fed diet with onion. Toghyani et al. 2011 reported that the reduction of serum LDL and raising HDL cholesterol by increasing garlic powder inclusion had been observed. Garlic has a dose-dependent inhibition effect on hepatic β-hydroxy-β-methylglutaryl coenzyme A (HMG-CoA) reductase, cholesterol 7α-hydroxylase, and fatty acid synthetase; diets containing an equivalent of 1, 2, 4, 6, and 8% garlic reduced serum cholesterol by 18, 21, 21, 24, and 25%, respectively (Qureshi et al., 1983 cited by Toghyani, et.al, 2011). Using of herbs as growth promoters in animal diet may not show any residual effects on consumers. An et al. (2015) reported that, using the onion extract used as feed additives in broilers has non toxic effects and safe as feed additives at an inclusion rate of 0.5% without having adverse effects on physiological responses. The concentrations of serum free cholesterol and triacylglycerol were significantly decreased in groups fed diets with onion extract.

Dietary garlic supplementation can reduce lower palmitic acid, SFA, serum and meat cholesterol content and increase unsaturated fatty acids (UFA) in chickens (Qureshi et al., 1983). Inhibition of cholesterol synthesis by garlic supplementation is due to, abundance of Compounds like allyl-disulfide or allyl-sulfhydryl groups (Singh and Porter, 2006). An et al. (2015) concluded that, onion extract may be able to use as substitute for in-feed antibiotics because the growth performance in chicks fed diet with onion extracts and could have beneficial effects in reducing the levels of blood free cholesterol and triacylglycerol of White mini broilers. Inclusion of garlic and onion in broiler diet affects lipid metabolism in the blood were listed in table (1).

Table 1: Effect of feeding onion and garlic on lipid metabolism

Item	Garlic level (mg kg^{-1})					
	Control	100	1000		SE	References
Plasma cholesterol	127.9^{a}	131.7 ^{a}	l22.2^{ab}		3.05	
Plasma HDL cholesterol (mg/dL^{-1})	101.4^{a}	109.8^{a}	102.7^{a}		3.05	Horton et al 1991
Item	**Control**	**Antibiotic**	**10 g/kg Onion**	**30 g/kg Onion**		
tryglyceride	120.67^{a}	111.25^{ab}	104.25ab	95.75^{b}	7.59	Goodarzi *et, al,2013*
Low density lipid	36.75	32.75	30.50	41.75	6.77	
	Control	**antibiotic**	**2kg**	**4g/kg**		
Triglyceride	50	49	49	47	7.39	
Total cholesterol	156	151	149	146	8.73	Toghyani et al, 2011

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iii. *Gastro intestinal development*

Inclusion of herbs in poultry diet initiates development and enzymatic activities of intestinal morph metric structure. Allicin content of allium family have ability to change the physiological activities of chicken. Allicin in garlic promotes the performance of the intestinal flora thereby improving digestion and enhancing the utilization of energy, leading to improved growth had been reported by (Pourali *et al.* 2010; okoleh and adeolu, 2014). Different researchers reported that positive effects of garic and onion on gut improvement. Ramakrishna *et al* (2003) also suggested that garlic supplementation enhances the activity of pancreatic enzymes and provides an environment for better absorption of nutrients Structure of intestinal mucosa reflects the health condition of intestine. Reported that the largest villus height in duodenum was observed in 1.5% Garlic supplemented group as compared to villus height. Using of garlic improved the villus height: crypt depth ratio compared to all other treatments. Saeid *et al.* (2013), who also reported the improved intestinal morphological characteristics like villi length and small crypts in birds receiving 0.5% garlic powder containing diet as compared to control.

iv. *Intestinal micro-flora*

The microbial population in the gastrointestinal tract of poultry plays an important role in normal digestive processes and health maintenance (Woods et al., 1999). Issa, et.al, (2012) noted that, improvement of total tract digestibility in broilers fed different levels of GP was probably due to herbal effects in increasing the microbial population especially the number of bacteria such as *E. coli*, *Clostridium* spp. and *Enterococci.* In order to increase growth performance of animals; concentration of the beneficial microorganism in animal gut are major determinant. Thus, researchers reported that, supplementation of allium species in broilers diet as alternatives of antibiotics May leads proliferation of beneficial micro organisms.

As cited by (Issa et. al 2012) The active principles of essential oils act as a digestibility enhancer, balancing the gut microbial ecosystem and stimulating the secretion of endogenous digestive enzymes and thus improving growth performance in poultry was reported by (Lovkova, et.al, 2001;Williams and Iosa, 2001;Cross et.al, 2007). As alternatives of antibiotics, herbs and photogenic products can control and limit the growth and colonization of a variety of pathogenic and nonpathogenic species of bacteria in chicks' gut. This may lead to a greater efficiency in the utilization of feed, resulting in increased growth and improved feed efficiency (Bedford, 2000). The Lactobacilli spp. population in birds supplemented with onion at the level of 30 g/kg was significantly higher than control birds listed in (table 2.) and birds supplemented with 10 g onion/kg at 42 days (Goodarzi et al. 2014).

Table 2: Effect of garlic and onion supplementation on microbial population

Variable	Controll	Antibiotic	Dietary Element		References
		virginiamyin	10g/kg onion	30g/kg of onion	
E.Coli	7.35	5.45	6.98	6.43	Goodarzi, 2014
Lacto Bacilus	4.98	5.53	5.05	5.68	

v. *Immune status*

Incorporations of onion in chicken diet induce positive effects on weight of lymphoid organs like, bursa of fabricius and spleen was listed in (table 3) due to, the active components of onion which have antibacterial, antintiviral, antifungal, anti inflammatory and antioxidant activities reported by (Lampe, 1999; Ibrahiem *et al.* 2004). Yamamoto and Glick (1998) the synthesis of immunoglobulins was higher in chicken with larger Bursa. Dafwang *et al.* [1995) reported that the effects of onion and garlic on immunoglobulins were similar to antibiotics. Garlic and cinnamon have potential broad antimicrobial activities, but, some authors reported that, none of the immune related parameters measured including antibody titers, lymphoid organs' weight, was neither positively nor negatively stimulated(Toghyani et al 2011; Jafari et al. 2008).

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Table 3: Effect of garlic and onion on lymphoid organ

	Con trol	Antibiotic	10 g/kg Onion	30 g/kg Onion	SEM1	References
Bursa	0.137[d]	0.165[b]	0.149[cd]	0.190a	0.010	
Spleen	0.111[b]	0.139[ab]	0.138[ab]	0.148a	0.005	Goodarzi *et al,2013*
	controll	0.3% of	0.5%			
Bursa of Fabricius (g/100 g)	0.32	0.29	0.33		0.02	*An et al. (2015)*
Spleen (g/100 g BW)	0.12	0.16	0.15	0.12	0.01	
parametres	control	3% garlic	5% garlic			
bursa	1.36	1.18	2.14	±0.42		Eligab et.al, 2013
spleeen	1.67[a]	1.01[b]	1.23[b]	±0.12		
thymus	5.81	6.02	6.19	±1.62		

Abcd; letter subscript indicates, significance difference among the treatments
BW: body weight

vi. *Carcass quality*

Inclusion of herbal products have been used as growth promoters the ingredients found in herbs used as digestion stimulants and facilitates growth of broiler chicken, therefore effect of onion and garlic extract on body weight gain, feed conversion efficiency had reported by (Frankic et al., 2009; Jo et al. 2009; Goodarzi et al., 2013)

Aji et al. (2011) also reported that inclusion of garlic and onion in chicks feed diet had been shown high body weight gain than control. Where as It has been appeared that inclusion of onion and garlic into broiler diets did not have adverse effects on feed intake so that effect of onion and garlic on different parameters of broiler chicken was indicated in table(4)

Table 4: Effect onion and garlic on carcass yield of broiler chicken

Treatment		Controll	25mg/d/bird		50mg/d/bird	100mg/d/bird	References
onion	LWkg	*1.95±0.38*	2.20±0.19		2.41±0.11	2.57±0.13	
	DWkg	1.39±0.27	1.53±0.15		1.69±0.10	1.83±0.16	Slyndra,2011
	Carcass yield%	71.28	69.5		70.12	72.2	
		controll	.3%	.5%		SEM	
Onion	Final BW (g/bird)	890.6a	882.0[ab]	880.3 [ab]		3.78	
	BW gain (g/d/bird)	25.1[a]		24.8ab	24.7[ab]	0.13	*An et al. (2015)*
	Carcass%	67.32		66.3	66.3	0.47	
Garlic	LWkg/bird	2.04±0.29	2.15±0.21		2.37±0.17	*2.65±0.09*	Slyranda, 2011
	DWkg/bird	1.43±0.23	1.51±0.26		1.66±0.20	1.85±0.11	
	Carcass yield%	70.1	70.23		71.12	71.2	
	level	controll	3%		5%	Se	
Garlic	IBWg/bird	47.90	45.10		48.60	±1.04	Eligab,2013

abce subscript letter indicates they have significance difference towards the row
BW=Body weight, LBW=live body weight, FCR= feed conversion ratio
CW=Carcass Weight. FBW=Final body weight

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c) *Characteristics of garlic and onion*

i. *Antimicrobial activity*

Garlic and onion have been used for centuries in several societies against parasitic, fungal, bacterial and viral causing pathogens. As mentioned in review articles of (Corzo-Martı´nez et al.2007) chemical characterization of sulphur compounds has allowed the plants to have antimicrobial effects against paracite, bacteria, protozoa, fungi and viral infection Allicin, ajoene and other organo-sulphur compounds from garlic are also effective antiprotozoals. Antiparasitic properties of onion extracts towards different strains of Leishmania and T. vaginalis have been reported as well (Saleheen et. al, 2004). In addition to inhibitory effects against pathogenic bacteria, onions and garlic have been found to promote beneficial microorganisms.

The organosulfur compounds are believed to possess anti-inflammatory, anti-allergic, anti-microbial, and anti-thrombotic activity by inhibition of cyclooxygenase and lipoxygenase enzymes (Block et al., 1997). Onions and garlic contain fructooligos accharides (FOS), prebiotics which are non-digestible ingredients fermented by bifido-bacteria in the body that help maintain the health of the gut and colon (Gibson, 1998). Onions are composed of 2.8% FOS (wet wt.) and 1.0% FOS in garlic (National onion association, undated) whereas, (Oligosaccharides have been proposed as a key food ingredient for the future. Also, according to review of(Corzo-Martı´nez et al, 2007) garlic and onion could be added like functional ingredients into ''fast foods'', highly consumed products in the present society, providing them antioxidant compounds, as quercetin, prebiotics compounds(FOS), or mineral nutrients, such as selenium, to prevent nutritional deficiencies .The anti-oxidative effects of onions have been associated with a reduced risk of neurodegenerative disorders, cancer, cataract formation, ulcer development and prevention of vascular and heart disease through inhibition of lipid per oxidation and lowering of low density lipoprotein (Shutenko et al., 1999), Hertog and Katan, 1998; Sanderson et al., 1999; Suzuki et al., 1998; Frèmont et al., 1998; Aviram et al., 1999; Kaneko and Baba, 1999).

ii. *Antioxidant properties*

According to (Noureddine, 2005) biological properties of Allium extracts possessed variable but, interesting antioxidant activities. These properties were significantly correlated to total phenolics content which was high in red, purple onions and garlic. However, in addition to phenolic compounds, sulfur compounds could be involved in the assessment of the antioxidant properties. Heat treatment reduced the antioxidant activity of the extracts; however, heating should be carefully considered when *Allium* plants are used in food preparation or cooking for antioxidant protection (Noureddine, 2005).Antioxidant activity from a high intake of fruits and vegetables has been reported to prevent alteration of DNA by reactive oxygen species. Flavonoids, ever-present in the herbs, whereas their antioxidative effects has been widely studied (Hertog and Katan, 1998). Onions are known to contain anthocyanins and the flavonoids quercetin and kaempferol (Rhodes and Price, 1996).

Quercetin have beneficial effects against many diseases and disorders including cataracts, cardiovascular disease as well as cancer of the breast, colon, ovarian, gastric, lung, and bladder. In addition to quercetin, onions contain the phyto-chemicals known as disulfides, tri-sulfides, cepaene, and vinyl dithiins. These compounds have a variety of health-functional properties, including anticancer and antimicrobial activities (national onion association, https://www. Onions-usa.org/all-about-onions/onion-health-research). Onions contain *more* polyphenols than even garlic or leeks, and are one of the best sources of a type of polyphenol called flavonoids, especially the flavonoid quercetin. further, as reported by the National Onion Association, onions are considered a dietary anti-carcinogen and inhibitory effects of onion. (http://www.ncbi.nlm.nih.gov/pubmed/17093154)

Table 5: Summary of the antioxidant properties for garlic (Allium sativum L.) and red onion (Allium cepa L.)

Sample	Phenolic content	References
Garlic	37.60 ±2.31 mg GAE/100g	
Red onion	53.43 ±1.72 mg GAE/100g	Che Othman, et.al,2011

GAE=.gallic acid equivalents (mg= milligram)

d) *Economic benefits of onion and garlic as feed additives*

In poultry industry feed additives have been widely used for long period of time as contrivance to increase animal productivity related to growth, feed efficiency and health condition. About 80% of domestic animals have been fed synthetic compounds for the purpose of either medication or growth promotion (Lee et al., 2001). Cost of Feed accounts for 60-80% of the total expenses in poultry production. Any operation must

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have clear targets how to optimize feed efficiency and reduce feed cost and work daily towards those targets (Zekic et al., 2010).

Recently, many researchers are working with searching herbal feed additives to replace antibiotics. Even, researches are conducted on different plants there should be accepted based on their feasibility in economic aspect.

As aresult, economic feasibility of garlic and onions had been reported by different authors but it depend on amount plants, part of plant used and availability of plant parts to the area.

Zekic et al., (2014) concluded that the addition of commercial garlic powder in amount of 2% in broilers Chicken diet had significant influence on production performance, higher final body weight, as well as on the nutritive and technological quality of chicken breast meat.

Sylandra, (2011) revealed that treatment of birds with *25 mg* and 50 mg of onion per day caused a reduction in their feeding cost. Conversely, 100 mg of onion increased the feeding cost of the birds .According to (Ashayerizadeh *et* al, 2009), feed is a major segment of production in poultry industry thus efforts are usually made in poultry industry to increase the efficiency of feed utilization to minimize per unit cost of production. This could be the direct consequence of the increased feed intake observed with feeding of onion at this dose level. While ,Treatment of birds with garlic at all the dose regimens also caused an increase in the feeding cost of the birds when compared to the control birds, the highest increase being that with 100_{mg} of garlic.

Boseleng (2012) revealed that the addition of 1.5% and 3%garlic on the sunshine chicken ration resulted to higher body weights and weight gain, better FCR and lower feed conversion ratio, and total feed cost to produce a kilogram in weight. Also, okoleh and adeolu (2014) demonstrated that, Inclusion of 14g per kilogram of diet garlic powder gave the least cost-benefit ratio, implying that it is the best diet from the economic point of iew.

III. Conclusion And Recommendation

Onion and garlic are the most available plants widely used on the world for their therapeutic effect and medicinal value. Recently the use of both plants as growth promoting factors are well accepted among many commertial farm now days, onion and garlic could be used to improve the performance of broiler chickens however, more studies need to be done to establish the appropriate amount, age and other favorable conditions under which the best result can be achieved with these plant materials (Sylandra, 2011).

Garlic and onion supplementation in animal diets drastically decrease total serum cholesterol, Low density level and very low density lipoproteins (VLDL) with significant increase in the level of high density lipoproteins (HDL).In other ways, in most of the studies on different percentage of inclusion had been reported differently .The choice for the low dose of onion and garlic used to decrease adverse effects of high dose garlic and onion reported by other researchers. being the fact , garlic and onion was reported to cause hemolytic anemia at 4% level in feed (Oboh, 2004) while onion given at *5,* 10, 14, 20 and *25*% of meal caused hemolytic anemia, decreased packed cell volume, hemoglobin concentration and red blood cell. Onion and garlic should be used, with in diet, not only for their organoleptic characteristics but also for the potential and verified biological activities. Therefore, the works which had been reported on garlic concerning level of ingredients are variable whereas, Eligab,et. Al, (2013) indicated that, dietary inclusion of garlic in broiler diet at 3% dose shown high production performance with higher doses, while some of researchers indicated inclusion of garlic in broilers diet does not shown any effects on production parameters of broiler chicken. Concerning the onion ingredients found in onion like phenolic compound and (fos) seems higher than that of garlic but, availability of information on onion was insufficient especially, using as growth promoters in animal diet. Therefore, further research will be intended for more evidences to get optimum level of garlic and onion which to be incorporated in broiler ration without any adverse effect on the products particularly focusing on onions.

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Value Chain Analysis of Red Pepper: The Case of Mareko District, Guragie Zone, Southern Ethiopia

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Abstract- The study was conducted at Mareko Woreda to undertake red pepper value chain analysis and examine the factors that affect the supply of red pepper. The area is known for its surplus production of red pepper. The study has focused on the market channel, conduct, performance of red pepper markets and the main constraints of volume of red pepper supply. Structured questionnaire, focus group discussions, key informant interviews and field observation were used for generating the data. The channel in which, retailers buy red pepper directly from farmers and they in turn sell the red pepper directly to the consumer's outlooks as the 1st important channel in the study area in terms of volume transacted. About 78.3% of the red pepper producers sold the red pepper by the price set of both parties based on negotiation. With regard to the payment strategy, about 79.17 % of sample farmers sold their product on cash. Traders took a total of 87.75% out of the total profit margin; specifically, among traders, processors profit margin constitutes the highest share (30.71%) followed by retailors (20.49%). The result from the econometric analysis show that, education level of the household head, Average lagged price, Proportion of land allocated for red pepper production, experience of the house hold head were found to have positive influence on marketable supply of red pepper. Likewise, Average input price and diseases were found to influence marketable supply of negatively.

Keywords: *mareko woreda, marketing cost, marketing margin, profitability, red pepper, supply factors.*

GJSFR-D Classification: *FOR Code: 070199*



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Mekdes Dessie [α], Mufti Jailan [σ] & Habtamu Mosi [ρ]

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Keywords: mareko woreda, marketing cost, marketing margin, profitability, red pepper, supply factors.

I. Introduction

In many developing countries including Ethiopia, agriculture plays a vibrant role in promoting economic growth and development. The importance of agriculture in Ethiopia is evidenced by its share in GDP (43%), its employment generation (80%), share of export (70%) and providing about 70% raw material for the industries in the country in 2012/13(UNDP, 2013). Furthermore, 90% of the poor earn their livelihood from this sector (Yu *et al.* 2011). Thus, it is not surprising that policy action in Ethiopia is largely based on influencing the dynamism of the agricultural sector.

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The globalized markets demand consistent supply of higher quality products that meet new standards for food quality and safety and hence increase the comparative advantages of large scale commercial farmers, processors and supermarket chains. Small and medium scale operators and smallholder farmers that supply them find it difficult to penetrate and exploit international markets which require value added products, in situations where local capacity and participation in the value addition process is limited by insufficient innovative product development and diversification to meet market requirements. The full exploitation of opportunities presented by these markets requires development of innovative market linkages and addressing specific consumer needs and diversification of agricultural products (Jema Haji, 2008).

Ethiopia has a comparative advantage in a number of horticultural commodities due to its favorable climate, proximity to European and Middle Eastern markets and cheap labor. However, the production of horticultural crops is much less than the production of food grains in the country. On average, more than 2,399,566 tons of vegetables and fruits are produced by public and private commercial farms (less than 2% of the total crop production) (EIA, 2012).

The past history of pepper in Ethiopia is possibly the most earliest than any other vegetable product (EEPA, 2014). Ethiopians have strong attachment to red pepper, which has high value principally for its high pungency. The fine powdered pungent product is an indispensable flavoring and coloring ingredient in the common traditional sauce "Wot" whereas; the green pod is consumed as a vegetable with other food items. There is a general belief among Ethiopians that a person who frequently consumes hot pepper has resistance to various diseases. The average daily consumption of hot pepper by Ethiopian adult is estimated 15 gram, which is higher than tomatoes and most other vegetables (EEPA, 2014).

Red pepper is a crop of high value in both domestic and export markets. Since it is a an industrial crop, it generates employment to urban and rural workers. The main processed product, oleoresin, is exported to different countries and the spiced ground is supplied to local market. Oleoresin that is used for food coloring is extracted from red pepper for export

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purpose. The deep red colored cultivars have a very high processing demand in the country (EEPA, 2014).

Farmers in Ethiopia are more focused on the production part without having adequate market information about their products. Agricultural marketing has become highly complex and difficult involving very large and long marketing channels, a large number of middlemen, many types of physical, social, economic and facilitating marketing functions and services. The majority of farmers are marginal, small, scattered, illiterate and unorganized. They do not have sufficient time, knowledge and skills for the scientific marketing of their produce. In the absence of well- developed markets, marketing facilities, and marketing efficiency, farmers are at disadvantage by selling their increased marketable surplus to traders in the market as they get low prices (Jema Haji, 2008).

Red pepper is widely cultivated in different agro- ecologies of Ethiopia. The Ethiopian Export Promotion Agency (EEPA, 2014) has carried out a spice potential market study in Amhara, Oromiya and SNNPRS, and it identified that the land coverage for pepper in the three regions. The total production of pepper in the country for the year 2016/2017 Ethiopian main cropping season (Meher) was estimated at 3.1 million quintals. On average 75% of pepper production is for market in SNNPRS (CSA, 2016). The share of the region in the total production of red pepper in the country constitutes 69%, followed by Amahara region, which produces about 27% of the total production in the country CSA (2016). In 2014/2015 production year the total cultivated land and production in the region was 67,072 hectare and 1, 970,068 quintal respectively (CSA, 2016).

The findings from this study are believed to be helpful in reducing the information gap on red pepper and contributing to work better understanding on improved strategies for reorienting marketing system for the benefit of smallholder farmers, traders, and other market participants. Analyzing the challenges in pepper marketing would indicate the gaps to improve pepper production and marketing and benefit policy makers and implementers in the area to fill the gaps. In addition to this it will also help to make appropriate marketing decisions by the producers, consumers, traders, investors, and others.

The study is also used to suggest strategies for smooth integration among production and marketing by referring to root causes for supply and marketing problems starting from production till the consumption of the product. In addition to this red pepper price currently increase more than previous time so study on value chain of red pepper today is important to identify whether producers gets the right share or not. This study, therefore, is initiated with the purpose of investigating the pepper value chains and factors affecting red pepper supply to the market in Mareko.

II. Research Methodology

a) *Description of the Study Area*

This study was conducted in five rural *kebeles* in Mareko *woreda* which is known for its red pepper production. Mareko is one of the *woredas* in the Southern Nations, Nationalities, and Peoples' Region of Ethiopia. Part of the Gurage Zone, It comprises 25 rural and one urban kebele administrations which are found in dry woinadega agro-ecological zone. The woreda is located about 136 km from the zonal capital, Wolkite. The woreda is bordered in the south by the Silte zone in the east and north by Oromia region, and in the west by Meskan woreda (MWFEDO, 2014). The topography district is characterized by flat (80%) and hill (20%) lands. The altitude of the district ranges between 1800 to 2076 meters above sea level.

b) *Sampling Technique and Sample Size*

In this study a two-stage sampling technique was used to select red pepper producers. The district has one urban and 25 rural *Kebles*. In the first stage five major red peppers producing *Kebles* were selected purposively based on its potential for red pepper production and marketing. In the second stage among the households that exist in the five *Kebles* red pepper producers were selected using random sampling technique. Accordingly, the sample size for this study was based on the rule of thumb $N \geq 50+8m$; where 'N' is sample size and 'm' is the number of explanatory variables (Xi) where i=1, 2…11 (Green, 2003). Hence, 120 respondents from five *Kebles* of Mareko *woreda* were selected and interviewed.

The trader surveys were conducted on market in urban areas/ towns in which a good sample of pepper traders existed. On the basis of flow of pepper, three markets (kosha, ensano, and butagira) were selected, which are the main pepper marketing sites in the study areas. An additional criterion used to select survey sites was the availability of secondary price data for some of the markets.

Due to the absence of reliable information on the population of traders in these areas, cluster sampling technique was conducted in the selected markets.

Therefore, in this study an attempt was made to select representative sample whenever possible using cluster sampling by incorporating licensed and un-licensed traders, and to include respondents from each of the following categories: wholesalers, collector retailer and processor. The total number of traders interviewed was 25 (6 wholesalers, 9 retailers, 5 collectors and 5 processors). To interview traders an independent check list was prepared and used.

c) *Type, Source and Method of Data Collection*

In this study, both the primary and secondary data were used. The primary data were collected

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through a household survey, focus group discussions (two separate FGDs that each contains 12 members were held in kosha and ensano kebles on feb.2017. The discussion was facilitated by the researcher together with the BoARD expert.) , key informant interviews (for this purpose key informants were selected from each *kebele* and a one-to-one interview was conducted with the selected key informants.) and field observations. To generate relevant secondary data on red pepper production and marketing, data was collected from different published and unpublished sources such as government institutions; the Bureau of Agriculture and Rural Development (BoARD), *Woreda* marketing agency reports and websites were referred.

d) Method of Data Analysis

In this study two types of data analysis methods were used. These include descriptive statistics and econometric analysis. The collected raw data were analyzed by applying the Micro-soft Office Excel and the Statistical Package for social Science (SPSS) version 20.

i. *Model Specification*

As the dependent variable, quantity of red pepper supply is a continuous variable the appropriate model is the OLS (Gujarat, 2004).

OLS regression is specified as:

$$Y_i = \alpha_i + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \cdots \ldots\ldots\ldots\ldots + \beta_i x_i + u_i$$

Where: Y_i = *quantity of red pepper supplied to market*

α_i = *Intercept*

β_1 = *Coefficient of* i^{th} *explanatory/independent variable*

x_1 = *Vector of explanatory variables*

u_i = *Disturbance term*

In this study the factors that affect the supply of red pepper to the market is estimated using the Multiple Regression Model (MRM). The main reason multiple linear regression model was used is to identify the most important factors that are associated with the amount of red pepper supplied by producer households in the area, and hence it enables to estimate how the included variables are related. The estimated coefficients indicate the effect of a change in the independent variables on the dependent variable (Green, 2003).

This model has both dependent and independent variables. The dependent variable is the quantity of red pepper supplied to the market. It is a continuous variable.

Accordingly, the red pepper supply model to be specified in this study is taken the following form. Quantity of red pepper supplied to the market is expressed as a function of several demographic and socioeconomic variables. Therefore:

QSRP = f (*EDLHH*, *PLAFRPP*, *FAMSZ*, *DFM*, *ALP*, API, DIS, *EXPHH*)

Where; *QSRP: Quantity of red pepper supplied to the market*

EDLHH: Education level of Household head
PLAFRPP: proportion of land allotted for red pepper production
FAMSZ: Family Size of household
DFM: distance from market
API: Average input price of red pepper
ALP: Average lagged price
DIS: Disease
EXPHH: experience of Household head on red pepper production

Table 1: Description of dependent and independent variables

Variables	Description of Variables	Unit of measurement	Expected sign
Quantity of red pepper supplied to the Market (QSRP)	Dependent variable indicating quantity of red pepper supplied	C=kilogram	+
Average lagged Price of red pepper (ALP)	Average lagged Price of red pepper per kilogram	C=ETB	+
Family Size (FAMSZ)	Household family size	C=Number	+/-
Education (EDLHH)	Educational status of the household head	C=Year of schooling	+
Distance from market (DFM)	Far to the market	C=kilometer	-
Proportion of Allotted land for red pepper production (PALFRPP)	*Allotted land for red pepper production*	C=hectare	+

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Average input price of red pepper(API)	Input price for red pepper	C=ETB	-
Experience of household(EXPHH)	experience of house hold head on red pepper production	C=Year of experience	+
Disease (DIS):	Occurrence of Diseases	D=1 if disease; =0 otherwise	-

2016, ETB= Ethiopian Birr, C= Continuous; D= dummy variable

For this particular study, Variance Inflation Factor (VIF) and Contingency Coefficient (CC) are used to test the existence of multicolliniarity for association among the continuous variables, and shows how the variance of an estimator is inflated by variables colinarity (Gujarati, 2004) and Contingency coefficient (CC) is used to check multicollinearity or association between dummy variables. For heteroskedasticity presence Breusch-Pagan test approach, is used.

III. Result and Discussion

This chapter presents the major findings of the study and it has three main sections. The first section deals with socio-economic characteristics of red pepper producers and traders. The second section presents market structure, conduct, and performance of red pepper. The third section is about the results of econometric analysis which contains the determinants of market supply of red pepper.

a) Socio-Economic Characteristics of Red Pepper Producers and Traders

In this part of the thesis, socio-economic characteristics of red pepper producers and traders are presented and discussed. First the socioeconomic characteristics of red pepper producers were presented, followed by the socioeconomic characteristics of traders.

b) Socio-Economic Characteristics of Red Pepper Producers

Sample size of red pepper producer households considered during the survey was 120. As shown in Table 2, out of total household heads interviewed 92.5% were male headed households while 7.5% were female headed households (Table 2). This is well approved by Bezabih and Hadra (2015) who reported less opportunity to females in Ethiopia where only two female households have participated from the total of 141 respondents. Wolday (1994) who indicated household size have had significant positive effect on quantity of marketed teff. Similarly Bezabih and Hadera (2015) have also witnessed that different sources of labor are employed in horticultural production of eastern Ethiopia where family labor takes the lion share for labor allotments.

Table 2: Demographic Characteristics red pepper producers

Variable	Description	Frequency	Percentage (%)
Sex	Male	111	92.5
	Female	9	7.5
Marital Status	Single	10	8.3
	Married	100	83.3
	Widowed	10	8.3
Age	Age group (24-50)	97	80.7
	Age group (>50)	23	19
Education	Primary school (0-4)	63	52.5
	Secondary school (5-8)	50	41.6
	High school (9-12)	7	5.8
Family Size	Small family size (<4)	6	4.9
	Medium family size (4-6)	49	40.9
	Large family size (7 -10)	57	47.5
	Very large family size (>10)	8	6.6

The result in table 3 shows that the average land holding size of the respondents was 1.16 ha which is lower than the national average holding size per household 1.25 ha (CSA, 2016) .

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Table 3: Land size and Experience of Household head

Variables	Min.	Max.	Mean	SD.
Total Land Size (ha)	0.50	4.00	1.1573	0.63961
Experience of HHH on farm (Years)	5.00	45.00	17.6833	7.86331
Experience of HHH off farm(Years)	0.00	11.00	0.8833	2.19695

Owing to inequitable access to information, large proportion of market power is captured by traders who have better access to mobile technology which favored traders to adverse risks of loss to this product. Access to market information is extremely limited in the Ethiopian grain market. At the producer level, farmers have very limited information on price prevailing even in nearby markets (Wolday, 1994).

Table 4: Access to extension service and market information

Variable	N	Description	Frequency	Percent
Access to Extension Service	120	Yes	114	95
		No	6	5
Access to Market Information	120	Yes	98	81.7
		No	22	18.3
Source of Market Information		1. Other red pepper trader	34	28.3
		2.Personal observation	19	15.8
		3.Telephone	55	45.8
		4.Broker	12	10.0

i. *Socio-Economic Characteristics of Red Pepper Traders*

Table 5 summarizes the socio-economic characteristics of traders in terms of gender and marital status. The survey result indicates that, 64% red pepper traders were males. About 72 percent of them were married, and 28 percent were single. . This is supported by IFAD (2004) report that shows in sub-Saharan countries women has less participation in trade activities.

Table 5: Socio-economic characteristics of sample traders (dummy variables)

Variable	Description	Frequency	Percentage (%)
Gender	Male	16	64
	Female	9	36
Marital Status	Single	7	28
	Married	18	72

Table 6: Socio-economic characteristics of sample traders (Continuous variables)

Variables	N	Min.	Max.	Average	S.D.
Age	25	27.00	51.00	40.64	6.45
Educ ation level	25	2.00	12.00	8.44	2.86
Family Size (in No)	25	2.00	9.00	5.40	1.83
Experience (in No of years)	25	3.00	12.00	7.36	2.59

c) *Market channels, Conduct, and Performance of Red Pepper*

i. *Marketing Channels of Red Pepper*

The main marketing channels identified from the point of production to the final consumer through different intermediaries were:

Channel-I: Farmers ⟶ consumers (3%)

The result shows that in this channel a total of about 6600 kg red pepper is transacted /marketed. As a result the channel stands as the least (8th) marketing channels in terms of volume.

Channel-II: Farmer ⟶ Cooperative ⟶ Consumers (5%)

In this channel a total of 11000 kg red pepper is transacted. As a result the channel was found to be the 7th most important channel in terms of volume.

Channel-III: Farmers ⟶ Processors ⟶ Consumers (7%)

In this channel about 15400 kg of red pepper is sold. This channels stands as the 6th important channel in the study area in terms of volume transacted.

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Channel-IV: Farmers → Collectors → Consumers (9%)

In this channel about 19800 kg of red pepper is sold. This channels stands as the 5th important channel in the study area in terms of volume transacted.

Channel-V: Farmers → Wholesalers → Retailers → Consumers (10%)

In this channel about 22000 kg of red pepper is sold. This channels stands as the 4th important channel in the study area in terms of volume transacted.

Channel-VI: Farmers → Wholesalers → Processors → Consumers (17%)

In this case the raw red pepper is sold to consumers by the processors after value addition processing is carried out. In this channel about 37400 kg of red pepper is sold. This channels stands as the 3rd important channel in the study area in terms of volume transacted.

Channel-VII: Farmers → Collector → Wholesalers → Consumers (19%)

In this channel a total of 41800kg red pepper is transacted. As a result the channel was found to be the 2nd most important channel in terms of volume.

Channel-VIII: Farmers → Retailers → Consumers (30%)

In this channel about 66000kg of red pepper is sold. This channels stands as the 1st important channel in the study area in terms of volume transacted.

ii. *Market conduct of Red pepper*

a. *Pricing Mechanism*

Table 7: Price setting mechanisms of red pepper in the study area

Description	Red pepper	
	No. of Resp. (N=120)	Percent (%)
Settled by Sellers	9	7.5
Settled by Buyers	17	14.2
By negotiation b/n buyer & seller	94	78.3

Mostly payment was made at a spot and after some hour the red pepper markets was takes place. Purchasing of red pepper done with credit by collectors and hence actual payment may be completed after the red pepper was transferred for respective customer; whereas when the products were sold directly by the processors hand to hand payment was used. The current finding was in agreement with red pepper payment strategy of farmers in Alaba and Silte *woreda* (Rehima, 2007).

iii. *Payment strategy*

Table 8: Payment mechanisms of red pepper in the study area

Description	Red pepper marketing	
	No. of Resp. (N=158)	Percent (%)
As soon as marketing takes place	95	79.17
After some hour	23	19.17
Other day after sale	2	1.7

With respect to market conduct it is not only the price setting strategy and the payment mechanisms but also misconducts both from traders and producers were identified. This is especially in relation with weighing the product. The results from both the household's survey and FGDs and KIIs indicated that during the marketing of the red pepper both traders and farmers cheat each other. This cheating from the side of the traders is by their attempt to minimize the volume/weight of the product during weighing, which was the major activity they usually do taking the advantage of the knowledge of farmers and mixing other variety of red pepper from neighboring areas. On the other hand, farmers cheat traders by watering red pepper and adding other foreign materials so as to increase the volume/weight of the pepper that had a great impact on the quality of the product. A farmer may use different methods of checking the weighing scale before selling. The mechanism may be checking one's weigh and comparing it at different weighing scales (or some weighing red pepper on different weighing scales). However, traders manipulate the weighing scale and all traders seem to talking the same language, cheating a minimum of 5 kg per qt. If the farmer refuses to sell, traders start to discuss on kilogram instead of price with farmers and with the intermediation of collectors.

a. *Market Performance of Red Pepper*

Marketing costs and benefit shares of actors in red pepper value chain

The arrangement of marketing cost revealed that farmers cost is the highest cost from the other actors. This is due to the higher cost of inputs used by red pepper farmers for production. Thus, the cost of input is the highest amount followed by processors cost and wholesalers cost.

A red pepper value chain actor adds value to the product as the product passes from one actor to another. In a way, the actors add value on the product through improving the quality by sorting, removing dusts and other trashes, changing the form, packing and time utility. Traders took a total of 87.75% out of the total profit margin; specifically, among traders, processors profit margin constitutes the highest share (30.71%)

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followed by retailors (20.49%). While farmers, doing all the work of producing red pepper and bearing the associated risks, took 12.25% of the profit margin. This impliedly, red pepper producers added 12.25% of the total value of red pepper in the *woreda*.

Table 9: Red pepper marketing costs and benefit shares of actors (per Kg)

Description	Actors					Horizontal Sum
	Farmers	Collectors	Wholesalers	Retailors	Processors	
Purchase price	0.0	46.2	48.3	49.0	51.2	194.7
Total Mktg Cost	20.60	1.5	4.75	4.3	15.8	46.95
Sale Price	56.6	51.4	62.2	64.5	106	340.7
Market Margin	56.6	5.2	13.4	15.5	54.8	145.5
% share of margin	38.9	3.57	9.21	10.65	37.67	100.00
Profit Margin	36	49.9	57.45	60.2	90.2	293.75
% share of profit	12.25	16.99	19.56	20.49	30.71	100.00

d) Determinants of Red Pepper Supply

i. *Data diagnosis*

Test for Multicolliniarity

In order to check the existence of multicolliniarity problems among continuous explanatory variable, VIF was employed. As all the VIF values of continuous explanatory variables in all models were less than 10, it shows that there was no serious multicolliniarity problem among continuous independent variables.

Test for heteroscedasticity

The presence of heteroscedasticity in this study was checked by using the Breusch-Pagan (BP) test. There was no heteroscedasticity problem in the model. In this specific model, as the Weighted Least Squares (WLS) method requires knowing of the conditional variance on which the weights are based and it is rarely the case, the robust standard errors was used to deal with heteroskedasticity (Stock and Watson, 2003).

The goodness of fit of the model

In this study, the coefficient of multiple determinations (R^2) of red pepper model was estimated 0.788. This means that 78.8%, of the variations in the dependent variable have been explained by the included explanatory variables in red pepper model; and rest determined by error terms.

e) Determinants of Red Pepper Market Supply

Estimates of the parameters of the variables expected to determine the marketable supply of red pepper are presented in table-10. The econometric analysis result (table-10) shows that among the eight (five continuous and one dummy) hypothesized determinants of market supply of red pepper; were found to be significant at 1%, 5% and 10% significant level. The relationship and the magnitude of the effect of each the significant explanatory variable on the market supply of red pepper is explained below.

Table 10: Estimation of the determinants of red pepper quantity supplied to the market

Variables	Red pepper		
	Coeff.	Std. Err.	T-value
(Constant)	32.622	56.502	0.577
EDUHH	2.183*	2.265	0.964
PLAFRPP	241.740***	55.434	4.361
FAMSZ	3.388	5.115	0.662
DFM	- 7.275	10.373	-0.701
API	-0.029***	0.007	-4.143
ALP	1.322**	0.601	2.199
DIS	-77.847***	15.623	-4.983
EXPHH	3.692**	1.486	2.485

- ***, **, and * are statistically significant at 1%, 5% and 10%, respectively.*
- *Dependent Variable = Quantity (in number) of Red Pepper supplied to the market.*
- *R-squared= for Red Pepper is 0.788; and*
- *Adj. R-squared = for Red Pepper is, 0.772*
- *Number of Observation= 120; Std. Err.: is robust*

Education level of the household head (EDUHH): Education has showed positive effect on red pepper quantity supplied to market with significance level of 10%. This means that, keeping other factors constant, if the education level of the household head increases by 1 year, the quantity of red peppers supplied to the market increases by about 2.183 kg. Astewel (2010)

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found that if paddy producer gets educated, the amount of paddy supplied to the market increases, which suggests that education improves level of sales that affects the marketable supply. This is also in line with previous study of Ayelech (2011), who found that if avocado producer gets educated, the amount of avocado supplied to the market increases. This result coincides with Tefera (2013) that states that education level is positively and significantly affected selling and securing of more income from bamboo in Sheka, Ethiopia. Amare (2013) also reported that education level of farmers exhibited a significant and positive effect on the marketed surplus of pepper

Proportion of land allocated for red pepper production (PLAFRPP): The result shows that proportion of land allocated for red pepper production influenced the quantity of supply of red pepper to the market positively at 1% significance level. Other factors being constant; if proportion of land allocated for red pepper production increases by one hectare, the amount of red pepper supplied to the market increases by 241.740 kg. The result of this study goes along with the findings of former studies. For instance, the finding of Kindie (2007), Rehima (2007), and Wendmagegn (2014) found that the amount of sesame, red pepper, and coffee respectively, produced per hectare of land by household affected market supply of each of the commodities significantly and positively. In support of the finding here, Kindie (2007) and Bosena (2008) indicated that the area of land allocated for sesame and cotton production in Metema District significantly and positively affected farm level market supply of sesame and cotton respectively.

Average input price of red pepper 2016(API): The econometric analysis result in table 10 shows that the input price of red pepper affected the marketed supply of red pepper significantly and negatively (at 1% significance level). The coefficient for the price of red pepper indicates that, other factors being constant, as the input price increases by one birr, the quantity of red pepper supplied to the market will decrease by 0.029 kg. The increasing price of agricultural inputs in the *woreda* is not only the production but it is also marketing problem farmers faced while buying agricultural inputs in the market prior to production. Thus, the increase in the price of input forces the farmers not only to reduce the intensity of input use (quantity of input) but also force them to switch to private dealers where there is no assurance of the quality. This in turn resulted in lowering yield and marketed surplus. Thus, the higher price requires due attention by the government.

Average lagged price of red pepper 2015 (ALP): As hypothesized, the model result shows that average lagged price positively and significantly affected red pepper quantity supplied to the market at 5% significance level. This means that, other factors being constant, a one birr increase in the lagged price of red pepper has caused an increase in 1.322 kg of marketable red pepper. Therefore this makes the supply to be directly related to the market price. This agrees with various empirical studies regarding the value chain of agricultural commodities. In this regard, study by Goetz (1992) on household marketing behavior in Sub-Saharan Africa found a significant and positive relationship between grain price and the probability of quantities sold. Also Wolelaw (2005) identified the major factors that affect the supply of rice at Fogera *Woreda and found* that price affected marketable supply of rice positively and significantly. In support of the findings of Ayelech (2011) on market chain analysis of fruits found that significant positive relationship between last year fruit price and quantity of fruits supplied to the market.

Disease (DIS): Prevalence of disease was one of the production problems encountered by farmers in the study area. Based on its occurrence, the most commonly occurred diseases were root rot disease. The result shows that disease influenced the quantity of supply of red pepper to the market negatively at 1% significance level. The negative sign indicates that the indirect relationship between the diseases and the quantity of red pepper they supplied to the market. Other factors being constant if a disease is occurred, the amount of red pepper supplied to the market decreases by 77.847 kg.

Experience of the household head (EXPHH): The result shows that the experience of the household head influenced the quantity of supply of red pepper to the market positively and significantly (at 5% significance level). The positive sign indicates the direct relationship between the experience of the household head and the quantity of red pepper supplied to the market. This means that, keeping other factors constant, as the experience of the household head increases by one year, the amount of red pepper supplied to the market increases by 3.692 kg. This could be from the fact that mostly in the study area harvesting and planting of red pepper is the responsibility of household head and when farmers got old the probability of harvesting much quantity of red pepper was higher owing to the experience/ specialization of the farmer. This is in line with finding of Addisu (2016) who illustrated as farmers experience increased the volume of onion supplied to market increased.

Traders took a total of 87.75% out of the total profit margin; specifically, among traders, processors profit margin constitutes the highest share (30.71%) followed by retailors (20.49%). As a result, producer share were smaller than traders so enhancing producers bargaining power through cooperative was important.

Marketing conduct shows that there was breed mix problem in the study area so that secured governments grant for mareko breed was essential.

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Validation and Sensitivity Analysis of InfoCrop Simulation Model for Growth and Yield of Indian Mustard Varieties at Allahabad

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Abstract- Field experiment was carried out at SHUATS, Allahabad, to study validation and sensitivity analysis of InfoCrop model with the data sets generated respectively during Rabi season of 2016-17. The main plot treatments and sub-plot treatment consisted three dates of sowing and cultivars (D1-25th October, D2-5th November and D3-15th November) and (V1- Parasmani, V2- Varuna and V3- SRM 777) using split plot design. The results revealed that simulation of growth and yield parameters were compared with observed data and results concluded that the model overestimates all the parameters within the acceptable range (<15%) with significant accuracy. Sensitivity analysis results indicated that increased in maximum and minimum temperature (1 ^{o}C above and below); increase in rainfall 10 to 20 percent; elevated CO2 from 390 to 490 ppm shows significant increase in seed yield but after beyond it adversely affect seed yield. Therefore, the validated InfoCrop can be used for prediction of phenology, estimates potential yield and it provide management option in resilience towards changing climatic conditions.

Keywords: *infocrop model, indian mustard, climate change, validation, sensitivity analysis.*

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Validation and Sensitivity Analysis of InfoCrop Simulation Model for Growth and Yield of Indian Mustard Varieties at Allahabad

Vijender Singh [α], Yogesh Kumar [σ] & Satyendra Nath [ρ]

Abstract- Field experiment was carried out at SHUATS, Allahabad, to study validation and sensitivity analysis of InfoCrop model with the data sets generated respectively during *Rabi* season of 2016-17. The main plot treatments and sub-plot treatment consisted three dates of sowing and cultivars (D_1-25th October, D_2-5th November and D_3-15th November) and (V_1- Parasmani, V_2- Varuna and V_3- SRM 777) using split plot design. The results revealed that simulation of growth and yield parameters were compared with observed data and results concluded that the model overestimates all the parameters within the acceptable range (<15%) with significant accuracy. Sensitivity analysis results indicated that increased in maximum and minimum temperature (1 ºC above and below); increase in rainfall 10 to 20 percent; elevated CO_2 from 390 to 490 ppm shows significant increase in seed yield but after beyond it adversely affect seed yield. Therefore, the validated InfoCrop can be used for prediction of phenology, estimates potential yield and it provide management option in resilience towards changing climatic conditions.

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I. Introduction

Rapeseed-mustard (*Brassica spp*.) is a major group of oilseeds crop of the world being grown in 53 countries across the six continents, Indian mustard (*Brassica juncea*) is the second important oilseed crop in India after groundnut sharing 27.8% in India's oilseed production. Indian-mustard is much sensitive to climatic variables; hence, climate change could have a significant effect on its production. One month delay in sowing from mid-October resulted in the loss of 40.6 percent in seed yield (Lallu, *et al.,* 2010). Weather parameter is very important which influence growth and yield of a mustard crop, therefore, largely governed by the change in growing environment such as date of sowing and water availability. Leaf area index plays an important role for crop growth based on its interception and utilization of PAR (Photo synthetically active radiation) for producing dry matter (Kumar *et al*., 2007) and with the delay in planting date, the higher mean temperature was experienced during flowering which led to accelerating the decrease of LAI and reduction of the flowering period (Poureisa and Nabipour, 2007).

According to IPCC assessment report (AR_4), global average temperature has increased by 0.74 ^{0}C over the last 100 years and projection of an increase in temperature about 1.8 to 4 ^{0}C by 2100. Global losses may account for 1 to 5 percent of GDP, but developing countries with tropical and sub-tropical climate are likely to suffer more losses. Temperature increases are likely to be higher during winter season and precipitation is likely to decrease (IPCC, 2007). IPCC and its global studies indicate that considerable probability of loss in crop production in India with increases in temperature (IPCC, 2014). InfoCrop simulation model is one of the user-friendly systems, dynamic crop growth model developed under Indian condition. This model has the capability to estimate the actual and potential yield, yield gaps and also to assess the impacts of climate variability and climate change. The model simulates the crop growth processes viz., phenology, photosynthesis, respiration, leaf area growth, assimilates partitioning, source-sink balance, nutrient uptake partitioning and transpiration (Aggarwal *et al*. 2006). InfoCrop model has been used for simulating potential rain-fed yields. It is used to optimize management, dates of planting, variety, irrigation and nitrogen fertilizer, assessing interactions among genotype, environment, management, and pests, yield forecast, yield loss assessment due to pests and greenhouse gas emissions (Aggarwal *et al.* 2004).

Study of the impact of climate change on crops needs simulation model, as it provides a means to quantify the effects of climate, soil, and management on crop growth, productivity and sustainability of agricultural production. These tools can reduce the expensive and time-consuming field experimentation as they can be used to extrapolate the results of research conducted in one season or location to another season, location, or management (Boomiraj *et al*. 2007). Boomiraj *et al*. (2010) observed that model can successfully simulate growth and yield of the mustard crop across different locations in India. The simulated yield of mustard was found to be sensitive to changes in atmospheric CO_2 and temperature variation. The

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objectives of this study, to quantify InfoCrop model on the mustard crop at Allahabad conditions, which show considerable potential to evaluate crops, varieties, and genotypes of mustard, cropping pattern and genetic potential for yield. The scientific information on simulation of growth and yield in mustard crop using modeling in Uttar Pradesh is lacking. Hence, keeping in view the importance of the study, the present investigation was carried out.

II. Materials and Method

a) Experimental Details

The experimental field data (2016-17) of Allahabad station comprising three dates of sowing (Rabi: D_1-25th Oct., D_2-5th Nov. and D_3-15th Nov.) and varieties (V_1- Parasmani, V_2- Varuna and V_3- SRM 777) through the field experiment laid out split-plot design was used for model calibration and validation. The package and practices for Indian mustard cultivation were followed as per the Sam Higginbottom University of Agriculture, Technology, and Sciences, Allahabad. Validation of model was performed by using different data sets on such as phenology, total dry matter, grain yield, harvesting index and test weight from the field experiment conducted at Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad.

b) InfoCrop v.2.0 model

InfoCrop is a dynamic crop-yield simulation model. This model was developed by Aggarwal (2009) at Center for Application of Systems Simulation, IARI, New Delhi. The inputs required for InfoCrop v. 2.0 model are listed separately in Table 1.

c) Calibration of the model

The models were run and validated by comparing the predicted output with observed parameters. Deviation of predicted from observed was calculated and accuracy of the model to predict different crop parameters was quantified, then the simulated was for the further study. The genetic coefficient of mustard for InfoCrop model is given in Table 2.

d) Validation

Validation of model will be performed by using different data sets on phenology, biological yield, seed yield, harvesting index and test weight from experiments conducted at Research farm, School of Forestry and Environment, SHUATS, Allahabad. For judging the performance of the InfoCrop model, validation results on major crop growth parameters such as phenology during crop growth and grain yield will be tested using various statistical parameters viz., mean absolute error (MAE), mean bias error (MBE), root mean square error (RMSE), and error %.

$$MAE = \sum_{i=1}^{n} [1P_i - O_i 1]/n$$

$$MBE = \sum_{i-1}^{n} [P_i - O_i]/n$$

$$RMSE = \left[\sum_{i=1}^{n} (P_i - O_i)^2 / n \right]^{1/2}$$

Error % = {(P – O) / O} * 100

Where, O = observed, P = simulated.

e) Sensitivity analysis

Sensitivity analysis are used to simulate the impact of change in maximum temperature (T_{max}) and minimum temperature (T_{min}), seasonal rainfall and elevated CO_2 concentration within a range of ±5 ^{o}C, ±10 % and 415 to 640 ppm, respectively, on the seed yield of three varieties of Indian mustard (*Brassica juncea*) *viz.* SRM 777, Varuna and Parasmani in context of changing climatic conditions.

III. Results and Discussion

a) Validation of Info Crop model

The model was calibrated and simulated in different plots of Parasmani, Varuna and SRM 777 in both sowing dates and season. Validation of model performed by different data sets on phenology, total dry matter, grain yield, harvesting index and test weight were simulated. Test criteria for various parameters of Mustard cv. SRM 777, Varuna and Parasmani using InfoCrop model during 2016-17.

b) Phenology

Test criteria of Phenology of mustard varieties using InfoCrop model during 2016-17 are presented in Table 3.

c) Days to start flowering (days)

The observed mean values of days to start flowering for three mustard cv. Parasmani, Varuna and SRM 777 were 37.33, 44.6 and 45.0, whereas the model simulated 39.67, 48.67 and 49.67 days respectively. Different test criteria involving difference measures to locate and quantify errors viz. MAE, MBE, RMSE, and PE computed for mustard varieties suggested that model was better for SRM 777 followed by Varuna and Parasmani for simulation of days to start of flowering. The mean percent error was observed higher for cv. SRM 777 (10.04) followed by Varuna (6.30) and Parasmani (5.06). This shows that model simulation was found better for cv. SRM 777 as compared to others in case of simulation of days to start flowering (days). Similar 41trend was observed for other test criteria for days to start flowering such as MAE, MBE, and RMSE. This clearly showed that model performance was found good for SRM 777 as compared to Varuna

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and Parasmani for simulation of days to start flowering. However, model overestimated the days to start flowering (days).

d) Days to maturity (days)

Days to maturity for Parasmani, Varuna and SRM 777 were observed as 144.33, 145.63 and 149.00 days while model simulated 150.67, 149.67 and 143.00 days, respectively. SRM 777 performed better and the model overestimated the days to maturity. The average percent error was overestimated by the model for mustard varieties. The mean percent error was observed higher for cv. SRM 777 (4.88) followed by Varuna (4.67) and Parasmani (4.71). This show that day to maturity simulation was found good for cv. SRM 777. The similar trend was observed by carrying out other tests such as MAE, MBE, and RMSE for days to maturity. The simulation performance of the model in respect of days taken to maturity was found good with an acceptable level.

e) Growth and yield parameter

Test criteria for growth and yield of mustard varieties using InfoCrop model during 2016-17 are presented in Table 4.

f) Test weight

The test weight obtained for cv. Parasmani, Varuna and SRM 777 were 4.66, 4.75 and 4.95 g, while model simulated higher values *i.e.* 5.91, 5.34 and 6.57 g, respectively. The average percent error for test weight was found 5.56 (Parasmani), 4.42 (Varuna) and 3.14 (SRM 777), respectively. The evaluation of MAE and MBE was found lower for cv. SRM 777 followed by Varuna and Parasmani except for MBE of SRM 777, respectively, but cv. Parasmani holds higher RMSE (0.57) values as compared to Varuna (0.42) and SRM 777 (0.51). The overall performance of test weight simulation was found under accepted range; however model overestimated the test weight.

g) Seed yield

The grain yield obtained for cv. Parasmani, Varuna, and SRM 777 were 1138.23, 121.32 and 1284.4 kg ha^{-1} while model simulated higher yield *i.e.* 1382.67, 1465.67 and 1451.67 kg ha^{-1} respectively. The test criteria computed by MAE, MBE, RMSE, and PE for both the cultivars suggested model performance was better for SRM 777 as compared to Varuna and Parasmani. The average percent error for grain yield of both the cultivars was overestimated by the model. The average percent error for grain yield was found 4.96 (SRM 777), 10.58 (Varuna) and 8.60 % (Parasmani), respectively. The mean percent error was found lower for SRM 777. The average error as computed by MAE (101.33), MBE (102.33) and RMSE (58.27) found lower for SRM 777 as compared to other cultivars. This shows that the evaluation of the model on an overall basis revealed that the yield simulation was found good with an acceptable level for mustard.

h) Biomass yield

The performance parameters for cv. SRM 777 was higher than Varuna and Parasmani for simulated biomass yield. The average percent error of biomass yield of all varieties was overestimated by the model. The average percent error for biomass yield was found 10.18 (SRM 777), 12.62 (Varuna) and 11.43 % (Parasmani), respectively. The average error as computed by MAE (1320.0), MBE (1320.0) and RMSE (1473.25) found lower for Parasmani as compared to other varieties. The biomass yield simulation was found good with an acceptable level for mustard.

i) Harvesting Index

The model performance in a simulation of Harvest Index was found good for cv. SRM 777(0.87 error %) as compared to Varuna (1.38 error %) and Parasmani (8.19 error %). More or less similar results were obtained in terms of other test criteria such as MAE, MBE, and RMSE for simulation of harvest index. Model underestimated the simulation results for cv. SRM 777 and Varuna and overestimated for Parasmani. Model performance was found good for cv. SRM 777 compared to other cultivars for HI simulation.

j) Sensitivity analysis

The increase in CO_2 concentration from 390 to 490 ppm enhanced the crop yield. Increase in CO_2 from 390 to 490 ppm with no change in temperature has resulted in 13–32 % increase in yield of mustard but further increase in CO_2 concentration reduced the percent increase in yield. Increase in rainfall during crop season, indicated the scope for improved dry matter production and increase in grain number.

k) Temperature

The increased in daily maximum temperature up to 3 ^{O}C resulted in increased in yield of mustard (figure 1). In plants, warmer temperature accelerates growth and development leading to less time for carbon fixation and biomass accumulation before seed set resulting in poor yield (Rawson, 1992; Morison, 1996). Similar results were supported by Singh *et al*. (2008), Easterling *et al*. (2007), Roy *et al*. (2005), Fischer *et al*. (2007), Mall *et al*. (2004), Long *et al*. (2006), Morrison and Stewart (2002), Chaudhari *et al*. (2009), Kumar *et al*. (2010), Bhagat *et al.* (2007) and Aggarwal *et al*. (2006).

The highest benefits in increased in yield was obtained by increasing minimum temperature from 2 ^{O}C above and -1 ^{O}C below from the crop season 2016-17. Similar results were supported by Singh *et al*. (2008), Easterling *et al*. (2007), Kumar *et al*. (2010), Chaudhari *et al*. (2009).

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l) Rainfall

The increase in rainfall (10 to 20 percent from the crop season 2016-17). It simulated the increased yield but after beyond it adversely affected crop growth and yield (figure 1). Similar results were reported by earlier workers Mall *et al*. (2004) and Singh *et al*. (2008).

m) CO_2 concentration

CO_2 concentration elevated 390 to 490 ppm from the present CO_2 concentration. It showed the positive impact on yield. An increase in crop yield in mustard crop after 490 ppm of CO_2 concentration, it produced warming effect which results decline in yield (figure 1). Similar results were reported by earlier workers Uperty *et al*. (2003), Rotter and Van de Geijn (1999).

IV. Conclusions

Simulation of mustard phenology, growth and yield attributes by InfoCrop model was within the acceptable limit. Therefore, the validated InfoCrop model can further be used for prediction of crop growth, phenology, potential and actual yield of the mustard crop under changing climate scenarios.

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Table 1: List of inputs required for InfoCrop

Input variables	Acronyms	Unit
Site data		
Latitude	LAT	Degree
Longitude	Long	Degree
Altitude	Alt	Meter
Daily weather data		
Date/year	dd-mm-yy	
Station number		
Julian days	JD	Days
Solar radiation	RDD	KJ m^{-2}
Maximum temperature	TMAX	°C
Minimum temperature	TMIN	°C
Vapour pressure	VP	K Pa
Wind Speed	WDST	$msec^{-1}$
Rainfall	TRAIN	Mm
Relative humidity morning	RHMIN	%
Soil texture/district master parameters		
pH of soil	PHFAC	
Electrical conductivity	EC	ds/m (0 to 1)
Slope	SLOPE	%
Thickness of layer	TKL	Mm
Sand content	SAND	%
Silt content	SILT	%
Clay content	CLAY	%
Saturation fraction	WCST	0 to 1
Field capacity fraction	WCFC	0 to 1
Wilting point fraction	WCWP	0 to 1
Saturation hydraulic conductivity	KSAT	mm/day
Bulk density	BDL	mg/m^3
Organic carbon	SOC	%
Soil moisture fraction at sowing	WCL	0.1 to 0.4
Initial soil ammonium	NHAPL	(1 to 40 kg/ha)
Initial soil nitrate	NOAPL	(1 to 50 kg/ha)
Crop data		
Crop name		
Input sowing depth	SOWDEP	Cm
Input seed rate	SEEDRT	kg ha^{-1}
Maximum possible crop duration		
Default sowing date	DATEB	Julian days of the year
Crop/variety management data		

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Thermal time for germination	TTGERM	degree day
Thermal time for seedling emergence to anthesis	TTVG	degree day
Thermal time for anthesis to maturity	TTGF	degree day
Base temperature	TGBD	°C
Optimum temperature	TOPT	°C
Maximum temperature	TMAX	°C
Relative growth rate of leaf area	LAII	°C/d
Specific leaf area	SLAVAR	m^2/mg
Index of greenness of leaves		Scale 0.8 to 1.2
Extinction coefficient of leaves at flowering		ha soil/ha leaf fraction
Radiation use efficiency	RUE	g/MJ/day
Root growth rate	RWRT	mm/d
Sensitivity of crop to flooding	FLDLCRP	Scale 1 to 1.2
Index of nitrogen	NI	Scale 0.7 to 1.0
Slope of storage organ number/m^2 to dry matter during storage organ formation	SOPOT	Storage organ/kg/day
Potential storage organ weight	POTGWT	mm/grain
Nitrogen content of storage organ	NUPTK	Fraction
Sensitivity of storage organ setting to low temperature	TPHIGH	Scale 0 to 1.5
Sensitivity of storage organ setting to high temperature	TPLOW	Scale 0 to 1.5

Table 2: Categorization of genetic coefficient of mustard for InfoCrop v.2.0 model

Genetic constant description	Acronyms	Unit
Thermal time for germination to emergence	TTGERM	degree day
Thermal time for seedling emergence to anthesis	TTVG	degree day
Thermal time for anthesis to maturity	TTGF	degree day
Specific leaf area of variety	SLAVAR	Fraction
Maximum number of grains per hectare	GNOMAX	grains per hectare

Table 3: Test criteria of mustard phenology using InfoCrop model during 2016-17

Parameters	Days to start flowering (days)			Days to maturity (days)		
Variety	PARASMANI	VARUNA	SRM 777	PARASMANI	VARUNA	SRM 777
OMV	37.33	44.6	45.00	144.33	145.63	149.00
SMV	3.06	1.53	1.80	4.51	4.16	4.58
SDo	39.67	48.67	49.67	150.67	149.67	156.33
SDs	5.86	1.52	1.52	7.71	2.51	7.02
MAE	1.03	2.00	3.67	1.33	8.33	4.33
MBE	2.07	4.67	3.67	6.00	3.33	4.33
RMSE	2.10	3.43	4.00	5.52	9.76	7.42
PE	5.06	6.30	10.04	4.71	4.67	4.88

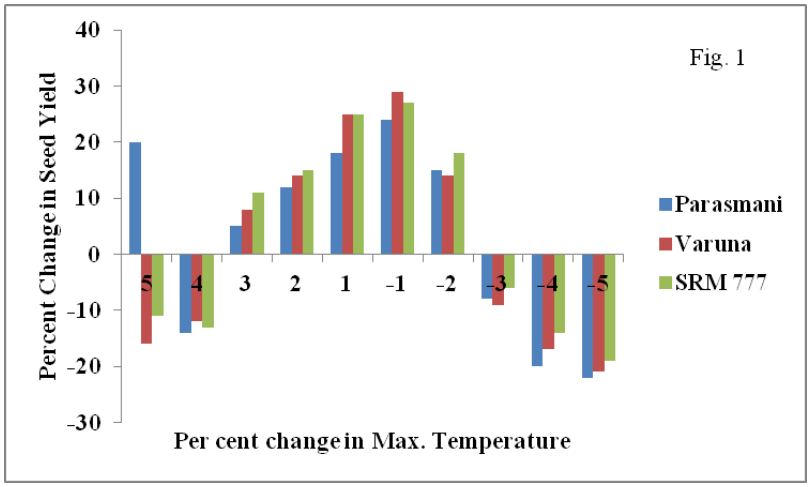
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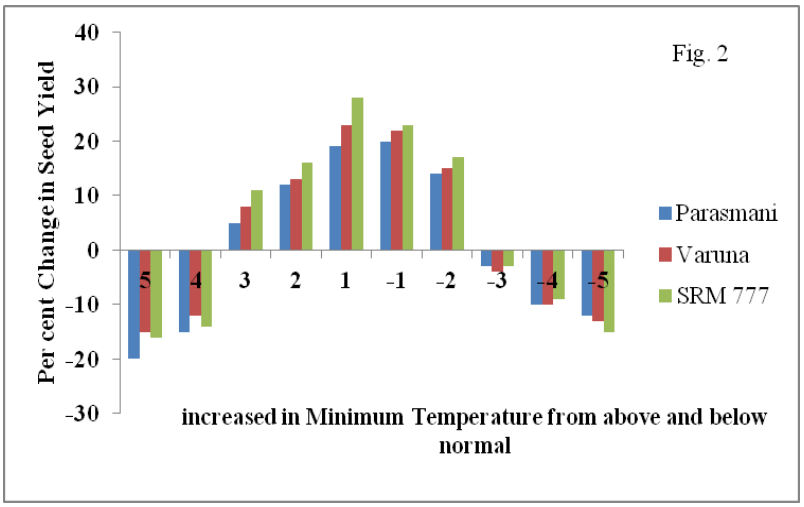
Table 4: Test criteria of yield and its attributes of mustard varieties using InfoCrop model during 2016-17

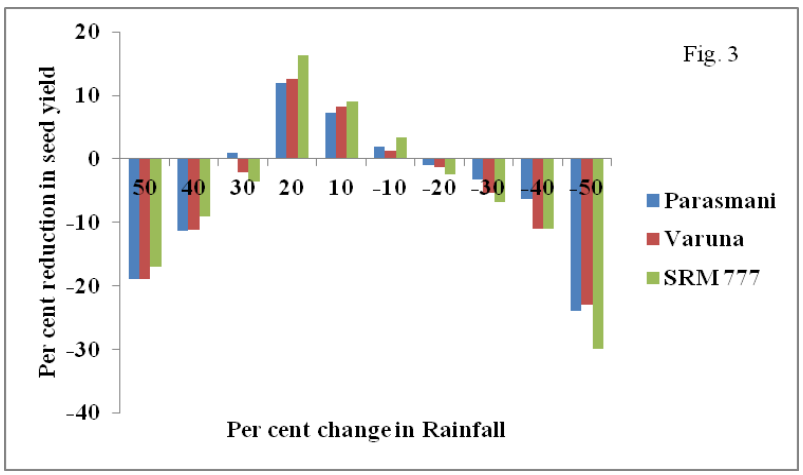
Parameters	Test weight (g)			Seed yield (kg/ha)			Biomass (kg/ha)			HI (%)		
Variety	PARASMANI	VARUNA	SRM 777	PARASMANI	VARUNA	SRM 777	PARASMANI	VARUNA	SRM 777	PARASMANI	VARUNA	SRM 777
OMV	4.66	4.75	4.95	1138.23	1214.32	1284.4	9891.0	10067.67	13186.0	11.50	12.58	13.47
SMV	0.88	0.88	0.89	396.99	396.11	400.56	1379.74	1389.25	1388.16	1.04	0.96	0.71
SDo	5.91	5.34	6.57	1382.67	1465.67	1451.67	10211.0	11313.33	12335.67	12.63	12.76	15.15
SDs	1.09	0.63	0.46	365.84	43.24	31.0	2181.04	1470.74	1300.63	0.40	1.76	0.22
MAE	0.50	0.35	0.31	209.0	105.67	101.33	1320.0	1245.67	1449.67	0.11	0.47	-0.87
MBE	0.50	0.35	0.38	209.0	105.67	102.33	1320.0	1373.67	1449.67	1.09	1.38	0.87
RMSE	0.57	0.42	0.51	220.51	208.05	58.27	1473.25	1649.55	1463.98	1.18	1.66	0.95
PE	5.56	4.42	3.14	8.60	10.58	4.96	11.43	12.62	10.18	1.96	4.19	3.31

Where OMV: observed mean value, SMV: simulated mean value, SDo: standard deviation of observed, SDs: standard deviation of simulation, MAE: mean absolute error, MBE: mean bias error, RMSE: root mean square error, PE: Percent error.

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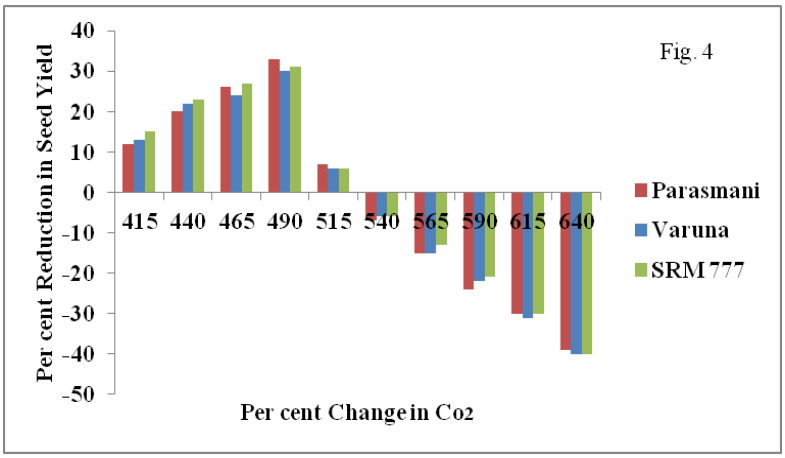


Figure 1: Depicting the InfoCrop simulation results of impact of change in (1) maximum temperature (T_{max}) (2) minimum temperature (T_{min}) (3) seasonal rainfall and (4) elevation in CO_2 concentration on the seed yield of all three varieties of mustard during the *Rabi*- 2016-2017

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Indebtedness Leading Punjab Farmers in to a DeathTrap: A Loan Waiver Needed

By M.L. Sehgal
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Abstract- This study details the causes as to how and why Punjab farmers fell into a never -ending cycle of debt which started right from the British Era but became graver with time. Slowly, it turned the state into a graveyard of farmers. The reasons for this poor plight of Punjab farmers are many which can be attributed to the various Governments both at the State and the Center, peasants themselves and to agricultural economists. The loss of resources due to trifurcation of Punjab (1st November, 1966) , the uncertain political atmosphere during the period of militancy, the absence of democratically elected state government for about a decade (3510 days) and bypassing of primary (agriculture) sector during Economic Liberalization period (initiated in June,1991) made Punjab an 'Orphan' state. The farmers failed to diversify as no right advice was forthcoming from the economists and continued with wheat and rice combination for which there were no takers of their surplus produce after some years. A Continual increase in the cost of agricultural inputs relative to a minimal increase in the MSP of the crops by the Centre, the pest attacks (whitefly on cotton), depleting underground water level in 80% area and excessive use of fertilizers and pesticides reduced the quality of both the soil and water of the state.

Keywords: indebtedness, fragmentation, holding, monocrop, depleting water level, fertilizers, green revolution, economic liberalization, cropping diversification, cropping intensity, contract farming, loan waiver, MSP.

GJSFR-D Classification: FOR Code: 070199



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Indebtedness Leading Punjab Farmers into a DeathTrap: A Loan Waiver Needed

M.L. Sehgal

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Keywords: indebtedness, fragmentation, holding, mono-crop, depleting water level, fertilizers, green revolution, economic liberalization, cropping diversification, cropping intensity, contract farming, loan waiver, MSP.

I. Introduction

Punjab, where agriculture is a way of life with about 75% of the population, constitutes 5036 thousand hectares of a geographical area of which 4145 thousand hectares comprises of the 6th most fertile soil of the world to make 82% of its land under cultivation in 2013-14[1] .As the farmers have sown 3703 thousand hectare area more than once, the total cropped area in 2013-14 was 7848 thousand hectare (3703.2+4145-3703) or 7848000.2.47105=193928004 acres. The irrigation facilities provided with the help of over 14 lakh tube-wells and five canals (Upper Bari Doab canal, Sirhind canal, Bhakra canal, Bist Doab canal, Indira Gandhi canal), an abundance of dedicated labor and great inherited agricultural skills of Punjab farmers have made it possible.

Since the advent of 'Green Revolution,' the state has made rapid progress in agricultural production having the highest annual rate of increase in the whole of India as indicated in Table: 1.

State	% Growth Rate
Punjab	6.4
Haryana	4.7
Gujarat	3.4
Uttar Pradesh	3.2
Rajasthan	2.4
Assam	2.3
West Bengal	2.2
Karnataka	2.1
Andhra Pradesh	2.0
Orissa	2.0
Madhya Pradesh	1.8
Maharashtra	1.7
Bihar	1.6
Tamil Naidu	1.0
Kerala	1.0
All India	2.6

Source: Nirvikar Singh & Deepali Singhal Kohli: The Green Revolution in Punjab, India: The Economics of Technological Change (1997)

The cropping intensity has increased from 126% to 189% in 2013-14[2].The area under wheat increased by 250.0%(1400000 hectares to 3500000 hectares) and production by 939.15% (1742000 ton to 16360000 ton) while the yield increased by377.8% (1244 kg/ hectare to 4700 kg/hectare) during 1960-61 to 2016-17.The area under rice has increased by 1437.44%(227000 hectares to 30360000 hectares); the production by 5503.93 (229000 ton to 12604000 ton) and the yield by 410.11% (1009 k gm/ hectare to 4138 k gm/ hectare) during the period 1965-66 to 2004-05. During the same duration, the Area, Average Yield, and Production of cotton are as under:

446000 hectare to 227000 hectare; 269 k gm/ hectare to 756 k gm/ hectare; 705000 bales to 1142000 bales [3]. The state has played a prominent role by achieving self sufficiency in food grains by contributing 43% wheat and 23% rice and 12% of the total food grains though Punjab has less than 2% of the total land of India(*www: Punjab data. com*) to the central pool. So,

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it is rightly called '*India's grain bowl'*. This has become possible by implementing various state & centrally sponsored schemes by various sections of Agriculture department.

The farmers promoted Zero-tillage technology for wheat. They cultivated an area of 3.14 lakh hectares during 2004-05 by this technique to save Rs. 42 crores [4].

II. Methodoly

The research material was collected both from the official and non-official agencies, An analytical approach was taken into consideration while using primary and secondary sources. The primary sources are available at National Archives of India, Delhi, Punjab State Archives, Chandigarh and Dwarka Das Library, Chandigarh. Among the many official documents some like Proceedings of the Government of India and Punjab (Political, Finance, and Agriculture Departments) were scanned. We collected bulk of the data from the Department of Agriculture, Government of Punjab (www.agripb.gov.in), Statistical Abstracts and Agricultural Census of Punjab, Fortnightly reports, Reports on the progress of education, Reports on the Progress of Industry, Reports of the Department of Finance and Agriculture, ENVIS Centre: Punjab: Status of Environment & Related Issues, Punjab Government Gazetteers and Punjab Agro Food grains Corporation. Also, data from the Department of Economics & Sociology, Department of Soil and Water Engineering, P.A.U., Ludhiana were helpful. The secondary sources like the relevant Journals, Newspapers, Magazines, Articles, Various Books and Unpublished Theses were assessed rigorously and thoroughly with an aim to present an objective and up-dated work as far as possible. Full forms of Acronyms used in this article are given in the Table: 2.

Table 2: List of Acronyms

Acronyms	Full Form
Jowar	Sorgum
Bajra	Pearl Millet
Ragi	Finger Millet
Arhar Dal	Split Red Gram
Urad Dal	Split Black Gram
Moong Dal	Split Green Gram
Toria	Short Duration Variety of Brassica Campestris
ENVIS	Environment Information System
HYV	High Yielding Varity
M.T.	Metric Ton(1000Kilogram)
Qtl	Quintal
Hectare	2.47105381 ≈ 2.50 Acres
CGWB	Central Ground Water Board
Majha	Amritsar, Tarn Tarn, Gurdaspur and Pathankot districts of Punjab
Malwa	Firozepur, Faridkot, Fazilka, Shri Mukatsar Sahib, Moga, Bathinda, Ludhiana, Barnala, Mansa, Sangrur, Patiala, Ropar, Mohali and F. G. Sahib
Doaba	Hoshiarpur, Kaputhala, Jalandhar and Shaheed Bhagat Singh Nagar districts
PDS	Public Distribution System
CAGR	Compound Annual Growth Rate
CARG	Compound Annual Rate of Growth
NASA	National Aeronautics and Space Administration of US
CF	Contract Farming
PAFC	Punjab Agro Food grains Corporation
GSDP	Gross State Domestic Product
MSP	Minimum Support Price
CRISIL	Credit Rating Information Services of India
A_2+FL cost	Actual paid out cost plus imputed value of family labor

III. Discussion

No doubt, in the agricultural economy of Punjab, the problem of indebtedness among peasants had been in existence even before the British rule. However, with the British occupation of Punjab, this problem had assumed a new dimension and took the form of an acute problem. In the 19th century, some developments such as commercialization of agriculture, the secular trends towards the rise in the level of prices, the establishment of the right to the creditor to seize land in satisfaction of debt and widening of the scope of alienable land rights took place [5]. Along with these changes, the agriculturists were subjected to three- fold exploitation. They had to bear a heavy burden of *lagan*, interest, and taxes. In market too, they were squarely robbed.

There had been a continuous and rapid growth, both in the number of debtors and in the amount of their debt in Punjab. In 1921, the total debt of the Punjab

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peasantry stood at Rs. 90 crores, while for entire British India, it was Rs. 600 crores [6]. By 1929, total debt for British India and Punjab was Rs. 900 crores and Rs. 135 crores respectively [7] and the consensus was that the volume of debt "has been increasing in the last century" [8].

In 1923, no less than 87% of the peasant proprietors were in debt to more than 40,000 money lenders[9].M.L. Darling (1925), who exhaustively dealt with the problem of indebtedness, concluded that:

The bulk of cultivators of Punjab is born in debt, live in debt and die in debt'[10]

But even after 70 years of independence, when farmers have hardly any issues with the burden of *lagan* and taxes, the condition and the living standard of the hardworking and resilient tiller of the soil are still pathetic. 85% farmers (both in the marginal and the large category) are under debt. A recent Punjabi University survey on the indebtedness among farmers and agricultural laborers [11] in rural Punjab has come out with the following data (Table: 3) for 2014-15.The banks advanced loans to the75.96 % of the farmers on 14% rate of interest. They used for it the following purposes (Table: 4):

Table 3: Debt on Punjab Farmers- A Glance

S. No.	Category	Debt(Rs)
1	Total Debt on the Farmers and Agricultural Laborers	69355Crore(693.55 billion)
2	Institutional Debt (banks, rural development banks)	56481Crore (564.81billion)
3	Moneylenders' Debt	12874Crore (128.74 billion)
4	Debt per house hold/ acre who own land	1,16,000
5	Debt per house hold / acre on each Agricultural Tiller	71203
6	Debt per house hold / acre on each Agricultural Labor	68,239

Table 4: Various Purposes for Taking Loans

Purpose	% of Total Loan
Farming	73.61
Health	1.68
Education	3.59
Social causes (Marriage)	6.85
Construction(Houses etc)	6.93

The Debt which in 2006-2007 was at Rs. 57,609 crores (Rs. 576.09 billion) swelled to 69355 crores (Rs 693.55 billion) in 2014-15.

Contrary to the belief that the exorbitant rate of interest charged by private moneylenders before India's partition was the main factor which had led to the debt on the farmers, the things, by and large, remain unchanged even though 82% of them have been advanced loans by some banks or the other government agencies while only 18% would fall prey to money-lenders with 14% and 24% interest per annum respectively. A majority of indebted farmer households belong to marginal (64%) and small (18%). The study, also, revealed that over 34% of marginal farmers and 20% small farmers (Table: 5) are living under the poverty line.

Table 5: Categories of Farmers with Average Holding

S. No.	Farmers' Category	Average Holding(Hectare)
1	Marginal	0.5-1.0
2	Small	1.0-2.0
3	Sem-Medium	2.0-4.0
4	Medium	4.0-10.0
5.	Large	Above 10.0

Farmers' suicide is not a new phenomenon in the state. Unable to pay the debt, Punjab is slowly turning into a graveyard of farmers. A study conducted by the three universities, Punjabi University Patiala, Guru Nanak Dev University, Amritsar and Punjab Agriculture University, Ludhiana, revealed that more than 10,000 farmers have committed suicides during the past 15 years of whom 4686 died during 2000-2011 by consuming poison while 2240 died due to other reasons, including drug addiction [11].A look at the profile of the farmers who committed suicide due to unseasonal rains reveals they are mostly marginal and small farmers, with land holdings up to five acres. They had taken additional land on lease at the rate of Rs.

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30,000-40,000, a well-established practice in the Malwa region (Bathinda, Sangrur, and Mansa being the most affected districts) accounts for 70 to 80 % of farmer suicides. Unseasonal rains and hailstorms since mid-February, 2015, had severely damaged the 7 lakh hectares of Rabi crops (wheat, cereals, mustard, and potato) [12].

It needs a thorough study to understand as to why the Punjab farmers are still in the trap of the indebtedness even in as latest as per 2014-15 data.

a) Various Stumbling Blocks for Farmers

The cumulative effect of an innumerable number of factors made the farmers to fall prey to the eagle-eyed moneylenders *(Shahukars).* The various reasons which played a wicked role in the aggregation of the debt on farmers both in the pre- and post-independence of India are briefly explained as follows:

b) Fragmentation of Land and a General Decline in Average Holding

(a) Fragmentation means that even the small size of land owned by a farmer may not be held by him in one contiguous plot but are scattered in tiny bits all over the village [13]. This excessive sub-division prevented the cultivator from sinking capital in the land, even when the total holding would, otherwise, be large enough for profitable cultivation [14]. This acted as a deterrent to full utilization of land as to live with his family, in some measure of comfort, a farmer in Punjab requires eight to ten acres of irrigated land. The more the fertility, the more it was spilled as fertility and population go together. Further, the decay of handicrafts unaccompanied by the corresponding expansion of the large- scale industries, the dissolution of the joint-family system and the development of separatist tendencies (supported by laws of inheritance and succession) became the principal causes of the smallness of the average holding and its excessive fragmentation. So the average operating land base for all categories of farms except for the marginal ones declined (Table: 6).

Table 6: Average Operational Land holdings in 22 districts of Punjab

District	Average Operational Holding(Hectare)				
	1970-71	1980-81	1990-91	2000-01	2010-11
Amritsar	2.08	3.64	3.52	3.28	3.09
Bhatinda	4.79	5.53	4.80	4.87	4.81
Faridkot	3.67	4.60	4.83	4.17	3.79
F.G. Sahib	Was created On 13th, April,1992			4.03	3.90
Ferozpur	2.94	4.46	4,54	5.62	5.14
Gurdashpur	2.11	2.60	2.64	3.19	2.43
Hoshiarpur	1.65	2.69	2.64	2.58	2.73
Jalandhar	2.44	3.99	3.41	3.44	4.56
Kapurthala	2.49	4.19	3.63	3.50	3.67
Ludhiana	3.46	4.44	3.91	3.95	4.43
Mansa	Was created On 13th, April,1992			4.67	4.32
Moga	Was created On 24th, Nov.,1995			3.88	3.27
Mohali	-------Was created On 14th, April,2006 -------				2.99
Muktsar	Was created On 24th, Nov.,1995			7.22	6.86
Nawanshar	Was created On 7th Nov., 1995			3.05	3.04
Patiala	4.63	4.95	4.05	4.60	3.95
Ropar	1.84	2.61	2.09	2.35	1.97
Sangrur	4.16	5.13	4.49	4.52	3.45
Taran Taran	On Martyrdom day of Guru Arjan Dev- 2006				3.22
Barnala	------- Was created On 27th, July,2011--------				4.16
Pathankot	------Was created On 27th, July,2011 ---------				
Fazilka	----------Do ----------				
Punjab	3.02	4.07	3.79	3.78	3.15

Source: Statistical Abstract of Punjab & Agricultural Census of Punjab

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(b) Among the bigger states, the % of wholly owned and self- operated operational holdings was lowest in Punjab in 1985-86(Table: 7).

Table 7: Land Ownership in 1985-86

State	% of Wholly owned/self-operated holdings
Punjab	84.9
Haryana	95.2
Gujarat	99.9
Uttar Pradesh	98.2
Rajasthan	98.2
Assam	89.9
West Bengal	88.5
Karnataka	99.8
Andhra Pradesh	99.5
Orissa	91.4
Madhya Pradesh	89.2
Maharashtra	98.3
Bihar	98.6
Tamil Naidu	99.4
Kerala	95.5
All India	95.9

Source: All India Report on Agriculture Census: 1985-86

These small holdings resulted in the multiplication of small fields involving a colossal waste of cultivable area because many more hedges, paths, etc. had to be laid down Again, scientific manuring and breeding of cattle were almost impossible and the margin of profit being small, complete ruin of the farmer was always susceptible if followed by a failure of the crops [15].Thus, the small size of holdings narrowed the margin of economic safety of the peasants.

c) Agricultural Land Values Appreciated

The sudden increase in the volume of the produce appreciated the value of agricultural land (from Rs. 41,675/hectare in 1985 to Rs. 3, 04,775/hectare in 1999) [16].Considering 2010 price index, this is equivalent to about Rs 12.9- 15.2 lakh/hectare [17] which made it an instant marketable entity and a source of profitable investment and credit for the landowners. This increase in the capacity to borrow led to the indebtedness increased the chances of the acquisition of land by moneyed classes [18]. In one of the reports, M.L. Darling records:

"Indebtedness seems due not to the impoverished condition of the people, but rather to the increased value of the land, which has given the zamindar [19] greater facilities for borrowing by improving the security, he has to offer"[20].

d) Social Ceremonies

The disturbing feature of indebtedness in India including Punjab was that the farmers would borrow for unproductive [6] causes. Such expenditures as those on marriages and other social ceremonies connected with birth, death, religious functions did not repay them. And since incomes of agriculturists, in general, were low, these provide no surplus for the return of these loans [21]. The lower strata of rural society had to suffer more as they could not even meet these minimum social obligations from their resources. So either they had to forgo their membership of the community or incurring a debt which might threaten their future viability [22].In short, the zamindars would not think of purchasing cattle, doing marriages or death ceremonies without borrowing money [23]. Prof. T. N. Carver, once, remarked [24]:

"Smallholdings, invariably, meant small incomes and in Punjab where expenditure was less determined by incomes than indicated by custom and necessity, small incomes sooner or later result in debt".

e) Excessive Love For litigation

'The people of the Punjab: says a report of 1925, 'are greatly addicted to litigation, and the litigation is of a more serious nature than in most other provinces' [25]. Temperament and ignorance alike made the peasant a firm believer in the efficacy of the direct method of settling the disputes which took the form of fatal fights and bloodshed. All of this led to litigation with all its consequences [26]. There was 2.3 crores pending cases, and 2.7 crores decided cases in the various courts of Punjab till 5th April 2016 when the e-courts Phase-I project culminated in the National Judicial Data Grid. The cost of obtaining justice in law courts of Punjab would amount to several thousand crores of rupees annually. Long drawn out litigation results in undesirable wastage of time and money, and adversely affected the agricultural operations. This litigation increased their expenditure, reduced their incomes and, thus, increased the need for loans [27].

f) Indebtedness of Farmers after Independence

In the fifties, there was enough of public investment in the Punjab state in dams, canals, electric power, rural roads and the towns which laid the foundation for the Green Revolution: an international movement launched in the 1960s to diminish world hunger which led to technological innovations. Developments in agriculture helped light manufacturing and services like tractors and pumps to a certain extent. Thankfully, the National Food Procurement policy reduced the market risks faced by farmers.

g) Mono-crop Culture and Saturation in Production Levels

Agriculture in Punjab suffers from 'Mono-crop Culture' of mainly wheat and paddy rotation. The high yielding varieties (HYVs) have replaced the multi-cropping pattern with the monoculture of wheat and rice resulting in exploitation of natural resources of the state especially water and soil, besides leading to loss of

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floral biodiversity which has caused an emergence of new and uncontrollable weeds (Table:8). And to add to their misery is that the 'Production Levels' of these crops have, already, touched a saturation point. [12].

The Table: 8 shows that the area under these two crops has increased from 47.36 % in 1970-71 to 97.88% in 2015-16. Again, according to 2015-16 data, the total production of rice in India was 104408 thousand metric ton and that in Punjab was 11823 units. It means Punjab produced 11.32% of the rice produced in India. The production of wheat in India was 92287 units and the same in Punjab was 16077 units, which is 17.4% of the wheat production in India. The total production of cereals (includes wheat, rice and other cereals like maize, jowar, bajra, barley) in India was 251566 units, and that in Punjab was 28400 units. According to these figures, Punjab produced almost 11.3% of the total cereals produced in the country.

Table 8: Production (%) of Majority Crops

Year	Crops (%)	
	Rice	Wheat
1970-71	6.87	40.49
1980-81	17.49	41.58
1990-91	26.86	43.63
2000-01	32.89	42.92
2007-08	33.15	44.31
2008-09	34.57	44.57
2009-10	35.58	44.72
2010-11	35.85	44.53
2011-12	29.41	50.25
2012-13	32.34	47.17
2013-14	31.21	48.81
2014-15	33.31	45.16
2015-16	41.48	56.40
2016-17	40.93	57.12

Source: Department of Agriculture, Punjab

h) The Continual rise in fixed and variable input costs

Growing a combination of wheat and rice has caused deterioration in the quality of the soil which would result in a decline in productivity. So a higher dose of fertilizers was needed to obtain the same yield which would increase the cost of production per hectare.

There is a continual rise in fixed and variable input costs like fertilizers, pesticides and weedicides, quality seeds and diesel annually (Tables: 9-17).

Table 9: Total Consumption of NPK (M. T.) and Consumption per Hectare

Year	Nitrogen (N)	Phosphorus (P)	Potassium (K)	Total NPK	Consumption (Kg/hectare)
1960-61	5	---	----	5	----
1970-71	175	31	7	213	37.50
1980-81	526	207	29	762	112.50
1990-91	877	328	15	1220	162.60
1995-96	1020	227	16	1263	166.31
2000-01	1008	282	23	1313	168.33
2005-06	1255	369	63	1687	214.00
2006-07	1299	354	38	1691	215.00
2007-08	1317	341	37	1695	213.00
2008-09	1332	379	55	1766	233.00
2009-10	1348	383	56	1786	226.00
2010-11	1403	435	73	1911	243.00
2011-12	1416	449	53	1918	243.00
2012-13	1436	416	33	1885	239.00
2013-14	1425	469	83	1977	251.00
2014-15	1730	460	60	2250	247.00
2015-16	1510	452	78	2040	257.00
2016-17	1409	386	46	1791	232.00

Source: Agriculture at a Glance, Department of Agriculture, Punjab

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Table 10: (a). Fertilizer Prices (Rs per M.T.) in Punjab

Period	Urea	DAP	SSP(P)	SSP(G)	NPK	MOP	NP
K-19.94	2760	7200	2260	2460	6940	3900	6600
R-1994-95	3320	7800	2480	2680	7540	3900	5960
K-1995	3320	9800	2600	2800	8940	4500	6000
R-1995-96	--do--	9575	--do--	--do--	--do--	--do--	--do--
K-1996	NA	NA	NA	NA	NA	NA	NA
Upto5.7.1996	--do--	--do--	--do--	--do--	--do--	--do--	--do--
6.7.96 to 8.9.96	--do--	7575	2440	2640	7415	4000	5231
From 9.9.1996	--do--	9100	2700	2900	7615	4500	6500
R- 1996-97	--do--	--do--	--do--	--do--	--do--	--do--	--do--
K-1997	3360	8300	2580	2780	7400	3700	--do--
R-1997-98	--do--	--do--	--do--	--do--	--do--	--do--	--do--
K- 1998	--do--	--do--	--do--	--do--	--do--	--do--	--do--
R-1998-99	--do--	--do--	--do--	--do--	--do--	--do--	--do--
K-1999	4000	8300	2550	--do--	--do--	--do--	--do--
R-1999-2000	--do--	--do--	--do--	--do--	--do--	--do--	--do--
K-2000-01	4600	8900	2680	2880	7960	4255	6880

Source: Department of Agriculture, Punjab; K= Kharif, R= Rabi; NA= Not available

Table 10: (b). Fertilizer* Prices in Punjab

Year	Name of Fertilizer(Rs. / Qtl)					
	Superphosphate	DAP	Urea (46%)	Muriate of Potash	Zinc sulphate	FYM
2007-08	370	935	478	445	2500	100
2008-09	--do--	--do--	--do--	--do--	--do-	-do-
2009-10	360	995	530	520	2500	100
2010-11	--	-do-	-do-	--do--	2800	--do--
2011-12	--	1820	540	1200	4000	120

Source: Department of Economics & Sociology, P. A. U., Ludhiana: New Fertilizers added

Table 11: Consumption of Insecticides and Pesticides

Year	Consumption(M.T.)
1980-81	3200
1990-91	6500
1995-96	7200
2000-01	6970
2005-06	5970
2006-07	5975
2007-08	5900
2008-09	5760
2009-10	5745
2010-11	5600
2011-12	5690
2012-13	5725
2013-14	5720
2014-15	5699
2015-16	5721
2016-17	5843
2017-18	6374

*Department of Agriculture, Punjab;*Technical grade*

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Table 12: Prices (Rs.) of Insecticides, Weedicides and Fungicides

Name of Chemical	Year				
	2008	2009	2010	2011	2012
Weedicides					
Arelon (per 500 gm)	160	150	160	170	210
Leader (per 13 gm)	325	340	320	325	400
Topik (per 160 gm)	----	----	350	350	400
2,4 D (per 500 gm)	100	300	200	220	220
Atrazine (per 500 gm)	140	150	150	150	150
Butachlor (per Litre)	160	200	180	180	180
Insecticides					
Chlorpyriphos (per Litre)	180	250	220	220	250
Malathion 50EC(per Litre)	180	180	250	240	240
Rogor 30EC (per Litre)	230	240	350	290	300
Cofidor (per Litre)	1800	1500	1600	1800	1800
Thiodan 35 EC (per Litre)	260	250	250	260	260
Dithane M-45 (per 500 gm)	115	200	170	180	250
Indofil M-45 (per 500 gm)	130	145	170	180	250
Stomp (per Litre)	430	390	450	450	450
Fungicides					
Blitox (per kg)	200	200	250	280	360
Streptocycline (per 6 gm)	35	32	30	35	40
Emisan-6 (per 100 gm)	40	50	60	55	65

Source: Department of Economics & Sociology, P. A. U., Ludhiana

Table 13: Total Seed Requirement for Crops in Punjab

Crop	Seed Requirement/ hectare(Kg)	Total seed Requirement(Ton)*			
		2007-08	2008-09	2009-10	200-11
Wheat	100.0	348700.0	352600.0	352200.0	351000.0
Gram	40.0	80.0	120.0	120.0	120.0
Sarson	3.8	112.7	108.9	116.4	120.2
Sunflower	5.0	100.0	100.0	110.0	75.0
Paddy	20.0	52180.0	54700.0	56040.0	56520.0
Maize	20.0	3080.0	3020.0	2780.0	2660.0
Sugarcane	87.5	9450.0	7087.5	5250.0	6125.0
Cotton	1.5	906.3	789.4	765.5	723.5

**Calculated by multiplying/ hectare requirement of seed with an area under a specific crop*

Table 14: Seed Prices of Crops in Punjab

Crop	Price of Seed (Rs/ Kg)				
	2008	2009	2010	2011	2012
Wheat	16.25	17.50	17.50	20.00	--
Gram	50.00	50.00	50.00	50.00	
Sarson	46.67	46.67	66.67	66.67	---
Sunflower	200.00	200.00	200.00	200.00	--
Paddy	18.75	18.75	18.75	25.00	25.00
Maize	50.00	50.00	70.00	70.00	150.00
Sugarcane	1.75	1.75	1.80	2.50	2.75
Cotton	2000.00	2000.00	2000.00	2000.00	2000.00

Source: Department of Economics & Sociology, P. A. U., Ludhiana

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Table 15: Number of Tractors and Tube Wells

Year	No of Tractors	Number of tractors/ 000' ha	No. of Tube wells*	Number of tube wells/ 000' ha
1970-71	5281	1.30	1.92	47.37
1980-81	118845	28.34	6.00	143.06
1990-91	289064	69.53	8.00	189.66
2000-01	434032	102.13	10.73	252.47
2007-08	485781	116.02	1246000	297.59
2008-09	492220	118.01	1276200	305.92
2009-10	498517	119.89	1375517	330.93
2010-11	504310	12129	13.81606	332.97

*Source: Statistical Abstract, Punjab; * Both Electrical and Diesel run*

Table 16: Prices of Selected Agricultural Machinery in Punjab

Year	Machinery		
	Tractor (35 HP)	Electrical motor	Diesel engine
2007-08	370000	23000	23000
2008-09	375000	23000	23000
2009-10	450000	23500	23000
2010-11	480000	28500	23500

Source: Department of Economics & Sociology, P. A. U., Ludhiana

Table 17: Variation in Diesel Prices per Liter (Rs) from 2004 to 2018

Year													
2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004
Diesel price per liter													
6833	51.67	46.01	66.79	52.03	43.47	40.01	38.51	32.76	34.04	32.85	33.65	29.77	24.35

On 21st, August, 2018, diesel price was Rs. 68.99 per liter

With crop intensification, agriculture in Punjab has become dependent on machinery. It helps in achieving the timeliness of various farm operations like seedbed preparation, sowing, spraying, harvesting, and threshing. Further, it offsets the challenges of labor shortages and drudgery involved in farm work and has considerably helped in overcoming the risk of unfavorable effects of weather on maturing crops. In addition , the farmers needed Tube wells and Tractors, a number of agricultural implements such as Seed-cum fertilizer drill, Knapsack spray pump , Vertical conveyer reaper, Tractor operated combine, Self- propelled combine, Thresher, Straw Reaper, Maize Sheller /thresher, Potato planter, Sugarcane cutter planter, Strip-till drill ,Zero till drill, Rotavator , Aero blast sprayer. Some of these implements are needed in lakh, others in thousand and a few in hundreds in the whole of the state. Their costs have been appreciating almost every year to make farming costing lakh for the farmers [28].

i) Labor and Agricultural Wages

With the onset of newer agricultural implants during the last over two decades, the farming also required the skilled persons in addition to the unskilled labor. With the dawn of education, the present generation of farmers would find them less interested in doing the hard agricultural work and thus their predecessors would depend upon the 'foreign labor'- the migrants from U.P. and Bihar states. The situation has become more and more acute with the passage of time as a bulk of the present generation of Punjab farmers has either migrated to the foreign countries or the metropolitans to green pastures. So the lesser number of the skilled and unskilled agricultural laborers was available. And by the law of demand and supply, it resulted in the increase in their wages and, thus, in the rise per hectare labor use.

The per hectare labor use in the cultivation of wheat, paddy and cotton collectively account for more than 85 % of the gross cropped area as given in the Table: 18.

Table 18: Labor Use per Hectare for Crops (Hours per Hectare)

Crop	Year		
	2007-08	2008-09	2009-10
Rice	402.54	417.19	NA*
Wheat	188.01	184.87	177.94
Cotton	803.30	717.78	NA*

Source: Estimates of the cost of cultivation scheme; NA= Not available

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Wages, also, determine the importance of a particular sector along with the socio-economic status of the people employed. Table: 19 shows that wage rates for various agricultural operations were, almost, doubled in between 2007 to 2011; implying towards a shortage of labor for the farming sector during the last years.

Table 19: Wages Paid to Agricultural and Skilled Laborers (Rs. per person day)

Crop	Year				
	2007	2008	2009	2010	2011**
Agricultural Laborer for					
Ploughing	106.24	128.12	143.92	151.82	205.50
Sowing	106.96	130.88	141.18	145.80	204.50
Weeding	105.21	123.10	129.75	149.47	197.25
Harvesting	114.08	127.62	186.00	189.61	203.00
Picking Cotton*	107.80		---	141.88	190.00
Other agricultural operations	106.48	137.41	144.25	144.43	215.00
Skilled Laborer					
Blacksmith	195.86	218.44	224.65	226.88	270.00
Carpenter	198.32	216.69	227.37	230.54	267.00

Source: Statistical Abstract; Female; ** During July 2011 to Nov 2011*

j) Depleting Water Level

Groundwater is the main source of irrigation in central Punjab. But the early plantation of rice is depleting the underground water. Thereby, the water table is going down at the rate of 3.0 meters / annum. 90 development blocks have already declared as black, and shallow tube wells are unable to draw water in many areas. Installation and deepening of tube wells due to the dipping water table are appreciating the cost of agriculture/ acre. With low remuneration leading to falling profit margins, the farming is becoming an economically unviable occupation for a small and marginal farmer since it is proving to be an uphill's task to arrange such a massive financial investments from their sources.

(a) The Table: 20 gives the district wise details of pre-monsoon minimum water level or maximum depth of water level. This gives an idea of continuous lowering of groundwater level during the last decade(2007-17) in Punjab indicating that the depletion is very fast in Patiala, Fatehgarh Sahib, Barnala, and Sangrur districts. There is hardly any lowering of groundwater In Muktsar and Nawanshahar districts. On the contrary, many parts of these districts are facing the problem of water logging. Also, a high level of salinity is making it unsuitable for human consumption or irrigation.

Table 20: Water Table (2007 to 2017)

District	Year	
	2007	2017
Amritsar	70	80
Bhatinda	55	80
Faridkot	43	49
F.G. Sahib	102	128
Firozpur	28	33
Gurdashpur	59	64
Hoshiarpur	75	86
Jalandhar	94	119
Kapurthala	90	93
Ludhiana	82	72
Mansa	55	85
Moga	96	69
Mohali	46	42
Muktsar	23	20
Nawanshar	46	48
Patiala	105	130
Ropar	97	107
Sangrur	95	109
Taran Taran	53	72
Barnala	70	109

Source: Punjab Data by Sukhminder Singh

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The data for the two new districts Pathankot and Fazilka but not available and are included in their parent districts, i.e. Gurdaspur and Firozpur respectively.

(b) One may expect that the water level will increase after the monsoon season, but in some districts the reverse may happen. This behavior is due to the fact that maximum consumption of groundwater is also during the same period from June to September (rainy season) due to the sowing of paddy crop.

(c) In early 2000, the water table started depleting alarmingly by a meter in Punjab, are the rate came down in 2010 when the state government enforced rule not to allow paddy transplantation before 15 June. The categories of blocks formed on the basis of underground water resources in Punjab during the various years are given in Table: 21:

Table 21: Blocks on the Basis of Underground Water Resources in Punjab

Category (%)	Year(Total blocks)					Over all % Area	Quality of water
	2000(138)	2005(137)	2010(138)	2015(138)	2016(148)		
Critical	11(7.97)	5(3.65)	3(2.17)	--	---	4.0	Brackish; Unfit for irrigation; SW Punjab
Sami critical	16(11.59)	4(2.92)	2(1.45)	---	----		
Over-exploited	73(52.90)	103(75.18)	110(79.7)	102(73.9)	110(74)	80.0	
Safe	38(27.54)	25(18.25)	23(16.67)	----	----	16.0	Kandi Area

**Jain, A.K., Department of soil and Water Engineering, P.A.U., Ludhiana*

In the overexploited blocks, the exploitation is more than 100%. In the critical category, the exploitation is above 85%. In the semi critical-category, the exploitation is 65-85% [29].

(d) The results for the two surveys conducted regarding the crisis of the depletion of the water table from January 2013 to January 2014 and then in between January 2015 to January 2016 are summarized in Tables 22-23:

Table 22: Percent of Wells and Water Levels (Jan 2014) and Comparison with Jan 2013

Water Level Range (Bgl)*	% of Wells	Comparison with January, 2013
0-2 m	8	(a)Water level rose in about 65% and fell in about 34% of wells (b)1% wells showed no change(c)Those showing rise, 58% showed a rise in 0-2 m and 3 % in 2-4 m (d) 30% of showed fall in 0-2 m (e) Maximum rise was 8.23 m and maximum fall was 4.70 m
2-5 m	16	
5-10	21	
10-20	34	
20-40	22	

Below ground level; Punjab: Status of Environment & Related Issues; Last Updated on 10th Feb 2016*

Table 23: Percentage of Wells and Water Levels (Jan 2016) and Comparison with Jan 2015

Water Level Range (Bgl)*	% of Wells	Comparison with January 2015
0-2 m	5	(a)Water level rose in about 36% and fell in about 62% of wells (b)1% wells showed no change(c)Those showing rise, 33% showed a rise in 0-2 m range (d) 56% of showed fall in 0-2 m range (e) Rise and fall is in the range of 0-2 m range
2-5 m	18	
5-10	22	
10-20	29	
20-40	26	

Below ground level; Punjab: Status of Environment & Related Issues; Last Updated on 10th Feb201*

The Moga, Sangrur, Patiala, Jalandhar districts recorded a deeper water level. The depth to water level recorded in the state during January 2016 ranges up to 38.57 m Bgl. Water [30].

(e) The groundwater depleted in Punjab by 55 centimeters in 2015. The Central Ground Water Board (CGWB) recorded fluctuations during January and May 2016 by monitoring 73% of wells covering 60% area of Punjab. It witnessed a fall in the water level. Barring some isolated pockets, the water table in Punjab goes down by 2 meters annually. Of the 142 blocks, 110 are rated as over

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exploited, particularly in central Punjab's Sangrur, Barnala, Jalandhar, Kapurthala, Nawanshahr and Patiala districts. In 22 blocks of southwest Punjab, underground water is not fit for human consumption or irrigation, and the area remains waterlogged during rains [31].

(f) The government's initiative to pledge nearly 1.25 lakh new tubewell connections may deepen Punjab's groundwater troubles. Currently, out of 141 agricultural blocks, 102 fall in the 'dark zone.' The water level is 200 feet or deeper in these blocks [32].

k) Deficient Rains

Increasing the number of tube wells would aggravate the groundwater crisis as Punjab did not receive normal rains for the past one decade. In the last 11 years (2005 – 2015), the rainfall during monsoon 2014 (June – September) was least in Punjab. Out of 20 districts for which data is available, the seven districts (35%) received scanty rainfall, nine districts (45%)district received deficient rainfall and only four districts(20%) in the state received normal rainfall. In short, excepting 2008, the state witnessed drought in rainfall. Even with the deficient rainfall, the farmers managed to save their crop by running all 14 lakh tube wells,' says Rajesh Vashishth, Joint Director Department of Agriculture's hydrology division [32]

(a) The average rainfall during 2005-15 is given in Table 24:

Table 24: Monsoon Rainfall (mm) in Punjab

Year	Actual	Normal	Departure (%)
2005	445.1	501.8	-11.3
206	436.5	-do-	-13
2007	340.4	-do-	-32.2
2008	603.7	-do-	+20.3
2009	323.4	-do-	-35.5
2010	458.2	496.4	-7.5
2011	459.2	496.4	-7.5
2012	266.0	496.3	-46.4
2013	477.9	491.5	-2.8
2014	243.9.	491.5	-50.4
2015	358.0	--do--	-26.2

I M D; Southwest Monsoon for Punjab

The districts along the Shivalik hills i.e., Gurdaspur, Pathankot, Hoshiarpur, and Ropar, receive maximum rainfall. The average annual rain fall is about 200 mm in the southwest region of Punjab which includes districts of Fazilka, Mansa, and Firozpur.

(b) The five-year annual average rain fall in Punjab was479.8.9 mm (47.99 cm) during the years 2012 to 2016. It was recorded as 437.6 mm during the five year period of 2006-2010.

(c) Data of the district wise average rain fall in Punjab during 2012-16 are given below in Table: 25.

Table 25: District wise Average Rainfall (mm)

District	Average Rainfall 2012-16
Amritsar	516.5
Bhatinda	381.1
Faridkot	457.6
F.G. Sahib	400.0
Firozpur	183.1
Gurdashpur	1167.8
Hoshiarpur	504.8
Jalandhar	411.0
Kapurthala	650.4
Ludhiana	443.8
Mansa	186.4
Moga	435.0
Mohali	616.6
Muktsar	374.8
Nawanshar	658.8
Patiala	421.5
Ropar	803.1
Sangrur	335.9
Taran Taran	370.9
Barnala	277.0
Punjab	479.81

Source: Punjab Data by Sukhminder Singh

The table shows that Gurdaspur district received the maximum rains (1167.8 mm) while Ferozpur district recorded the least rainfall (183.1 mm). Data for Pathankot and Fazilka are not available but are included in their parent districts i.e., Gurdaspur and Firozpur respectively. Dhar Kalan block in Pathankot district is the wettest place, and Abohar in the Fazilka district is the driest place in the state.

Almost 60-70% of annual rainfall in Punjab occurs during the monsoon season (July to September); being maximum in August and least in October and November. The Table: 26 represents the average monthly rainfall in the state during the five years period from 2012 to 2016(479.81mm).

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Table 26: Monthly Rainfall in Punjab

Month	Average Rainfall (mm)
January	19.5
February	22.7
March	31.9
April	16.1
May	14.4
June	56.3
July	116.0
August	124.4
September	62.7
October	7.3
November	1.6
December	6.9

Source: Punjab Data by Sukhminder Singh

l) Farmers cannot do without Moneylenders (Arhtiyas)

Cooperative societies provide short-term formal loans for the day to day agricultural expenditure. But for expenditure on costly inputs like installation of a submersible pump which may cost Rs. 3 lakh and even various households like providing education to the children, emergency medical expenses the loans, at any time of the day, is available to farmers only by *arhtiyas.* Farmers who take land on the lease for cultivation have to bear the extra cost of rent of land and expenses of cultivation since the institutional sources do not lend on such lands. Thus starts a vicious cycle of taking more costly loans. Further, the farmers have no choice but to sell their produce only through their lenders. The high production costs make it difficult to pay the farm rent despite the fact that the lease rent during this year is much less than the previous year (Rs 20-25K/ acre from Rs.30-35K/ acre). Ramanjit Singh Sikki, a Congress MLA representing Khadoor Sahib Assembly constituency (2017) remarks [33]:

"The only reason farmers are still taking land on a lease is to renew their bank limits and save them from becoming bankrupt socially."

m) Unemployed Man-power and low auxiliary non-farm income opportunities

Punjab, being a predominantly agricultural state, only the seasonal work is available to a vast majority of the ruralites who loiter away their time to result in colossal wastage of the man-power. The unemployed rural educated youth constitute approximately 54 % of the aggregate of rural unemployed in the state [16]. Paradoxically, the high level of mechanization in sowing, irrigation, and harvesting of paddy and wheat has progressively replaced human labor by machine labor. Power draught has virtually disappeared from the agricultural scene in Punjab [34]. A small holding of the land needed fever people from their respective families while other members would while away their precious time without any contribution to the family income. With such a meager income from the farming, it becomes impossible to lead a minimum quality of life. There are a few cottage industries available in the vicinity of their villages which could, well, serve as a mean to utilize the surplus labor force by employing them in some monetarily gainful work of their choice so that they live with the family and were also available in case of any need.

n) Green Revolution Aftermath: Drug Menace: Loss of Farming and Human Lives

Green revolution turned out to be a whole sort of good thing for the Agricultural Economy of Punjab as it created an enormous wealth up till the nineties. Mediocre left Punjab for green pastures and settled in other countries. The ones left were either affluent farmers (who would not like to migrate) or were paupers (who could not afford. Now this new progeny (generation) of the old hard working farmers has either access to immense wealth-*the jazzy cars* or were financially hard pressed. The former category of farmers would not want to *break their back* toiling in the farms and would give those jobs to the people from the states of Bihar and U.P. who are poor and were willing to do the hard farm labor. The second category of poor farmers with meager resources tried for some jobs, but would not get. Thus both types of young farmers were pushed towards the drugs- the former out of plenty *to get high* while latter category of farmers got addicted to drugs to *release their frustration*. But both type of farmers purchase drugs by selling their landed properties. This caused a decline in wealth, sale of the farms and loss of their precious health coupled with many other socio- economic problems. But even the large faring have started feeling the pinch as the fuel, farm machinery, labor and harvesting costs have all gone up, while crop realizations are plunging and thus the lease cost is declining.

o) Roles of State and Central Governments Viz. - A- Viz. Indebtedness of Farmers

The wrong policies and adverse political decisions of both the State and Central governments have also contributed to some extent, for the trap of the indebtedness of the Punjab farmers as follows:

p) Paid the price for the Trifurcation of Punjab

The trifurcation of Punjab into Punjab, Haryana, and Himachal (1st November 1966) had a severe effect on its resources. Himachal, received mineral resources and Haryana received fully developed industries near Delhi. Punjab could neither retain the minerals nor the industrial set up.

q) J.S. Sandhu and Arijit Singh wrote

"With the reorganization of the state in November 1966, developing industrial complex around Delhi fell to the share of Haryana and whatever mineral and forest resources that were available went over to the

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Himachal Pradesh. As a result, the growth of the industries in the state further suffered a setback"[35].

Also, Punjab lost a chunk of fertile soil though somewhat less than Punjab; of Ambala, Karnal, Kurukshetra, Kaithal, Faridabad to Haryana. It produced only 26 lakh ton of food grains in 1966, but today its production has reached over 163 lakh tones [35]. Despite having scant rainfall in several parts, Haryana, one of the smallest states in the country with 40 lakh hectares, has grown from a food deficient to a food surplus state. With just 1.5% of the country's land, make it the second biggest contributor to the national food basket. Its contribution is15%, i. e., wheat 58.56 lakh ton and rice 23.91lakh ton. It weakened the position of Punjab in the national political scene as Haryana became one of the leaders for political competition in the Hindi belt rather than remaining as a sub-region of Punjab. It would, now, compete with other states rather than with the 'elder brother' concerning resources [36].

r) Ignored the Warning Bells of the Seventies

Three points to note are:

(a) After over a decade of the Green Revolution [37], the warning signs started emerging as revolution benefitted the big farmers more than the small farmers. The middlemen who provided credit, access to inputs, and a channel for the quick sale of produce became important like the moneylenders who had always been a powerful group even during the pre-Independence era. The agriculture would not absorb enough labor. But the armed services recruitment as well as the migration of the farmers to the West proved to be a saving grace. The latter category of the peasants also brought an additional avenue for surplus rural labor.

(b) The global economy and the level of conflict in national politics deteriorated in the 1970s. There was chaos in Punjab in the eighties with enormous human, social and economic losses.

(c) To add to the misery, the state political leaders vied for competing with one another and even with their sister states like Haryana and Himachal for natural resources such as river water and electric power, rather than finding out the means to move Punjab state up in the development ladder.

s) No Elected Government for about a decade

In Punjab, President's rule remained in vogue for about ten years (3510 days) due to the disturbed political conditions. So there was no state leader who would take care of the state which had been trifurcated only two decades before and have faced a severe crunch in its economic resources.

t) Punjab Neglected during Economic Liberalization

Even in the era of Economic Liberalization initiated in June 1991 by Rao and Singh [38] Punjab remained the worst placed due to the lack of any credible state leadership. The decontrol on industrial licensing did not help in giving a flip to the investments in the state. Since the Agriculture remained heavily regulated and dominated by the production of grains for the PDS, did not benefit from decontrol. Supporters of economic reforms consisting of liberalization policy patronized secondary (Industrial) and tertiary (Manufacture and Employment) sectors as indicated by their respective growth during the period. Punjab economy grew at the rate of 5.3% per annum as against 5.5% in the case of the national economy[39] Agriculture, a sub-sector of the primary sector started experiencing a decline in its growth rate while Secondary and Tertiary sectors experienced positive growth as given in Table:27 [40]:

Table 27: Growth of Primary, Secondary and Tertiary Sectors during Economic Liberalization

Year	% Growth Rate of		
	Primary (Agriculture) Sector	Secondary(industrial) Sector	& Employment) Sector
1980-85	4.66	4.93	2.97
1985-90	3.91	5.75	4.46

Declining rate of the growth in the Agriculture sector was the practice of concentration, i.e., to grow wheat and rice. "The other food crops such as maize, bajara, barley, gram, and pulse were neglected whose share in the total food grains were just 1.95% in 2011-12" [41].Support from the agricultural sector to the economy of Punjab decreased because the production level has reached to the point of saturation. The Table: 28 will prove this point for three major crops (wheat, rice, cotton) in different sets of years that the yield has increased but their rates of growth is slowly declining. It, also, proves that the Green Revolution has outlived its utility. There is no scope to increase the area under agriculture as almost 99 % of the cultivable land is under plow, and already 97.9 % of the cultivated area is under irrigation [42].

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Table 28: Saturation in Average Yield

Crop	Year	Average Yield*
Wheat	1990-91	3715
	2010-11	4693
	2011-12	5097
Rice	1990-91	3229
	2010-11	3828
	2011-12	3741
Cotton	1990-91	285
	2010-11	472
	2011-12	449

**k g/hectare*

The stagnation in agriculture was not the only problem. Also, the declining quality of soil and falling levels of groundwater due to the excessive use of water and increasing use of fertilizers and pesticides used to enhance the productivity played havoc in agriculture. Agriculture is still the most contributing sector in the economy of Punjab with wheat and rice remaining dominant at the cost of other crops in the post liberalized period

u) Distorted Cropping Diversification and Depleting Ground Water Level

Encouraged by the increased subsidies for water, electric power and fertilizer by the central and state governments, farmers of Punjab opted for Water-intensive crops such as rice and sugarcane at the cost of decrease in the acreage under wheat(Table:29). This diversification created new lock-in effects for farmers to go with those for wheat under the PDS. In addition, it caused a severe depletion of the ground water table which had to be pumped at alarmingly high rates, increasingly micronutrient deficient soil and, thus, an imminent ecological disaster. The area under wheat and paddy has increased manifolds during the last five decades, whereas the area under oilseeds, pulses, maize other cereals has decreased sharply while the area under cotton & sugarcane has remained more or less constant.

Table 29: A Shift in Cropping Pattern of Nine Important Crops From 1960 to 2017 (Area in' 000 hectares)

Crop	60-61	70-71	80-81	90-91	2000-01	05-06	06--07	08-09	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17
Wheat	1400	2299	2812	3273	3408	3469	3467	3526	3522	5310	3527	3517	3512	3505	3808	3500
Rice	227	390	1183	2015	2611	2647	2621	2734	2802	2831	2811	2845	2851	2894	2980	3033
Cotton	446	397	648	701	474	557	614	528	511	484	516	481	446	420	339	285
Maize	327	555	304	183	164	151	154	152	140	134	129	131	130	126	127	118
Sugarcane	133	128	71	101	121	85	99	81	60	70	80	83	89	94	92	87
Pulses	903	33	58	73	42	32	30	25	21	98	61	64	56	49	44	78.6
Mustard	54	57	77	70	64	51	46	35	39	41	38	41.8	38.7	41.8	32	50.7
Sesamum	4	15	17	18	19	0.2	0.2	0.2	?	?	?	?	?	?	48	20
Groundnut	67	174	83	11	4	3	4.4	3	3	2	2	1.6	1.3	1.4	1.9	1.5

Source: Department of Agriculture, Government of Punjab (www.agripb.gov.in)

Of course, the cropping intensity (ratio of net sown area to gross cropped area) in Punjab has increased sharply from 126% in 1960-61 to 191 in 2012-13 as given in the Table: 30.Punjab can boast of having the highest cropping intensity in the country closely followed by West Bengal (185%), Haryana (181%), Himachal Pradesh (173%) and Orissa (162%) as compared to all India percentage 138% [43]. But it has severely affected the soil fertility as it leaves no time for the natural rejuvenation.

Table 30: Cropping Intensity in Punjab State

Year	1960- 61	1970-71	1980-81	1990-91	2000-01	2007-08	2008-09	2009-10	2011-12	2012-13	2013-14
Intensity (%)	126.0	140.0	161.0	178.0	186.0	187.96	189.69	189.00	190.00	191.00	189.00

Source: Department of Agriculture, Punjab, 2013

Compound Annual Growth Rates (CAGR) for the main crops of state in 8th to 11th five year plans and for the overall study period (1992-93 to- 2010-11) are presented in Table: 31. The data indicate that the major contributor towards wheat production over this period was the increase in the yield. Plan-wise major increase in wheat area, production and yield were observed during the 9th plan. Except potato, CAGR of the area of all other major crops in state viz. cotton, maize, pulses, oilseeds, and sugarcane during this period were found to be negative.

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Table 31: Overall Compound Growth rates of Major Crops

Crop	b	Overall (1992-93 to 2010-11)
Rice	A	1.56***
	P	2.79***
	Y	1.2***
Wheat	A	0.47***
	P	1.16***
	Y	0.69***
Maize	A	-1.47***
	P	2.18
	Y	3.71***
Gram	A	-12.48***
	P	-10.82***
	Y	1.86***
Sugarcane	A	-2.08*
	P	-2.87**
	Y	-0.23ns
Cotton	A	-1.56**
	P	2.29ns
	Y	3.91**
Potato	A	6.07***
	P	7.45***
	Y	1.32**
Total Cereals	A	0.82***
	P	1.78***
	Y	0.95***
Total Pulses	A	-9.86***
	P	-9.50***
	Y	0.41ns
Total foodgrains	A	0.73***
	P	1.76***
	Y	1.01***
Total oilseeds	A	-7.12***
	P	-6.89***
	Y	0.25ns

- *Constitutes initial four years of the plan; ns= Not significant*
  ****, ** and * Significant at 1, 5 and10 % level of probability*

b. A= Area in lakh hectare; P= Production in lakh ton and Y=Yield (Productivity) in kg / hectare

v) Misplaced Priorities of Punjab State

In Punjab, the number of electricity-operated tube wells have increased from 5 lakh in early 1980s to 12.5 lakh in 2001-02.The farmers installed about 3.25 lakh tube wells during1996-01 as the state government had announced free power to farmers in 1997 [43]. But the number of diesel-operated tube wells remained more or less the same since early 1990s, i .e., at about 1.5 lakh [43]. Fearing that Punjab may turn into a desert in 15- 20 years and degradation of the fertile agricultural land may become a problem, a study instituted by Central Ground Water Board (CGWB) for mapping of aquifers (underground bed) up to 300 meters. Also, NASA report cautions as:

"The National Aeronautics and Space Administration (NASA) of the US had, also, warned that agriculture output in Punjab and Haryana could collapse if groundwater is extracted ruthlessly and even the Central Ground Water Board has been issuing warning to Punjab for many years now".

Despite the warning, the government's initiative to pledge nearly 1.25 lakh new tube well connections this year is likely to deal a blow to the already depleting underground water level as it will initiate the farmers of the state to choose rice cultivation due to free irrigation facility. "The new connections would encourage farmers to go for more paddy cultivation which has an assured market and price. The 'diversification scheme' aiming to divert area from paddy to other crops will receive a major setback" [32]say experts in the state's Department of Agriculture. They further add that:

"Already, the area under cotton in the state has gone down by over 1.5 lakh hectares compared with last year's on fears of the white fly attack, and now a major portion of this cotton area may go under paddy"[32].

w) Possible Solutions

The government is very much aware of the agrarian crisis and rural suicides. It, acknowledges that the current cropping pattern is not viable and has

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put forward the crop-diversification policy. We start from a scratch:

x) Shelve Installing 1.25 Lakh New Tube wells

(a) At the onset, there is hardly any justification of installing more when there, already, exist 12.76 lakh electricity operated, and 1.50 lakh diesel operated tube wells[32] for an agricultural land area of about 42 lakh hectare; approximately 11 Lakh hectare of which is irrigated by canals [32]. More importantly, there is no justification in having 15 lakh tube wells for 11 lakh farmers in Punjab. The top experts in their respective fields also advise against the idea of dipping new tube wells because:

i. The release of 1.25 lakh tube well connections would cost over Rs 500 crores and the power subsidy in the state would rise to about Rs. 6,000 crores.
ii. During paddy season, when the rainfall is in deficit, running of 14 lakh tube wells simultaneously puts huge pressure on the groundwater which , on the average has gone down 200 feet or deeper in nearly 80% area of Punjab including the entire Majha and Doaba regions and some districts of Malwa like Patiala, Moga, Sangrur.
iii. In the current year, the state government has already waived off Rs. 5,484 crore as power bills of farmers.
iv. The cost of installing a 5 HP motor for irrigating two hectares of land costs anywhere between Rs 60,000 to Rs 65,000 to farmers. However, farmers, mostly, go for deeper tube wells due to depleting groundwater, and prefer, high-capacity motors of 7.5-12 HP which cost between Rs. 1.5 to 2.5 lakh per piece depending on the depth.

y) Promote Schemes for Less Water Consuming Kharif Crops

No doubt, the state government would spend about 6000 crores on the free power subsidy to the farmers, but they should also promote less water consuming crops and support their marketing with the power subsidy amount. A number of other steps to save underground water reserves such as the Contract Farming (CF) program (2002), New Agriculture Policy for State (2013) and passing the Punjab Preservation of Subsoil Water Act (2009) to divert areas under the water consuming rice crop towards other Kharif crops were not implemented vigorously. Contract Farming is essentially demand/market driven, unlike traditional farming that first produces a commodity and then looks for its market. Punjab Agro Food grains Corporation (PAFC) has succeeded in barley malting and is given in Table: 32. Also, Punjab farmers have also shown concern for contract farming in some other crops (Table: 33)

Table 32: Area (Hectares) under Malting Barley

Year	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
Area under Malting Barley	4850	6000	2800	2780	960	830

Source: Punjab Agro Food grains Corporation

Table 33: Area (Hectares) under Different Crops under Contract Farming

Crop	Year			
	2007-08	2008-09	2009-10	2010-11
Hyola	13273	14216	7254	---
Basmati Pure	33614	33606	31966	28322
Maize	45405	32827	33028	---
Green Pea	---	448	449	254
Potato Seed	---	---	1625	1671
Total	92292	81097	74322	30247

Source: Statistical Abstract, Punjab

The area under rice cultivation remains between 27-28 lakh hectares. But the production of a special brand of Punjab called "Flavored Basmati" is being encouraged by planting it over five lack hectares to produce about 20 lakh ton. Its export was, previously, refused by European and Arab countries because a quantity of pesticides/ k g was found to be more (1.0ppm) than the prescribed limit of 0.01ppm/k gm. P.A.U., Ludhiana has, now, recommended to replace certain pesticides for more effective brands [44].

z) Regulate Underground Water and Fertilizer/ Pesticides Usages

We find the groundwater at 200 feet. It is going at a lower level day by day and needs some efficient technologies to regulate it as it like a' *fixed deposit in a bank.*'[45]. Moreover there is no logic behind having a tube well for every 2.0-2.5 hectare. The excessive use of fertilizers and pesticides are now polluting the underground water and the produce of the farmers. The government needs to caution the farmers.

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aa) Loan Waiver – A Need of the Hour

According to the RBI report on the study of state government budgets, Punjab's annual debt is running at 31.4% of the gross state domestic product (GSDP) in 2015-16..It is the second highest rate of indebtedness, with West Bengal topping the charts with a debt to GSDP ratio32.9% in 2015-16 [46].There is three ways to pull out the state from its poor economic health:

(a) There are approximately 18.5 lakh of farming families in Punjab. About 65% are small and marginal. 70% of these families have access to institutional finance. Punjab government, like U.P. and Maharashtra states has announced a Rs. 24000crores loan waiver to the farmers [47]. This move will benefit 10.25 lakh farmers. About 8.75 lakh of these farmers own up to five acres of land. (b) As the water level has gone down critically, the government at the center should give subsidy on installing tube wells.(c)The Centre must announce a policy of crop diversification and give special packages for it.

bb) Create Employment for Punjabi Youth

A policy for creating employment for Punjab's youth must be in place both from the Centre and the state governments. Punjab being a predominantly agricultural state, only the seasonal work is available to a vast majority of rural people which results in colossal wastage of the manpower. Even the small holding of the land needed fever people from their respective families while the other members would while away their precious time without any contribution to the family income. The cottage industries can serve as a mean to utilize the surplus labor force by employing them in some work of their choice in some small industry in the vicinity of their villages. This way, they will supplement the income by living with their respective families, and will also available in case of any need. The paradox of the conflict between the rural unemployed youth and governments at the State and the Center is summarized by S.S. Gill [34] as follows:

There is generally a mismatch between the aspirations of the unemployed and the policies pursued for creating employment opportunities. Rural educated job-seekers aspire to secure white-collar government or semi-government jobs. On the other hand, the government is not willing to act as a major employer of such youth. Alternative opportunities for skill-development through vocational training have to be popularized at the village level. Simultaneously, the corporate sector has to be encouraged to enter the rural areas with their programs, so that employment generation activities are created. Self-employment skills have to be imparted and credit facilities made available for translating their aspirations into reality in rural areas.

The machinery of the Planning Commission needs to be activated with well thought-out policies and action program, as the task is colossal and calls for multi-directional co-operative efforts'.

cc) Finally a Relief: Government Approves Hike in MSP

Since the government wanted the rural incomes to be robust, it has given its approval for an increase of 4.13-52.47% for the 2018-19 than those of the 2017-18 M S P for 14 Kharif crops [48] which will cost the exchequer over 15,000 crores is higher than the full paid-out costs (A2+FL) by 50.09- 96.97%(Table: 34).

Table 34: Approved MSP for Kharif Crops from 2015-16 to 18-19 (Rs per Qtl)

Crop	Year	Variety	SP (Previous)*	MRP (2018-19)*	Increase(%) over2017-18	Return*over Cost (%)
Paddy	2017-18 [2016-17] 2015-16	Common	1550 [1470] (1410)	1750	200(12.90)	50.09
	2017-18 [2016-17] 2015-16	Grade-A	1590 [1510] (1450)	1770	180(11.32)	51.80
Jowar	2017-18 [2016-17] (2015-16)	Hybrid	1700 [1625] (1570)	2430	730 (42.94)	50.09
	2017-18 [2016-17] (2015-16)	Maldandi	1725 [1650] (1590)	2450	725(42.03)	51.33
Bajra	2017-18 [2016-17] (2015-16)	---	1425 [1330] (1275)	1950	525(36.84)	96.97

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Ragi	2017-18 [2016-17] (2015-16)	---	1900 [1725] (1650)	2897	997(52.47)	50.01
Maize	2017-18 [2016-17] (2015-16)	---	1425 [1365] (1325)	1700	275(19.30)	50.31
Arhar(Tur)	2017-18 [2016-17] (2015-16)	---	5450 [5050] (4625	5675	225(4.13)	65.36
Moong	2017-18 [2016-17] (2015-16)	---	5575 [5225] (4850)	6975	1400(25.11)	50.00
Urad	2017-18 [2016-17] (2015-16)	---	5400 [5000] (4625)	5600	200(3.70)	62.89
Groundnut	2017-18 [2016-17] (2015-16)	---	4450 [4220] (4030)	4890	440(9.89)	50.00
Sunflower Seed	2017-18 [2016-17] (2015-16)	---	4100 [3950] (3800)	5388	1288(31.42)	50.01
Soyabean	2017-18 [2016-17] (2015-16)	Yellow	3050 [2775] (2600)	3399	349(11.44)	50.01
Sesamum	2017-18 [2016-17] (2015-16)	---	5300 [5000] (4700)	6249	949(17.91)	50.01
Nigerseed	2017-18 [2016-17] (2015-16)	----	4050 [3825] (3650)	5877	1827(45.11)	50.01
Cotton(Staple)	2017-18 [2017-18] (2015-16)	Medium	4020 [3860] (3800)	5150	1130(28.11)	50.01
	2017-18 [2016-17] (2015-16)	Long	4320 [4160] (4100)	5450	1130(26.16)	58.75

- *Includes Bonus*

DK Joshi, Chief Economist at CRISIL says:

"The weighted average MSP increase (crop weights being the quantity procured last year) comes to around 13%. Assuming the procurement of Kharif crops would be as much as last year, the higher M S Ps would cost the government about `11,500 crores. But the actual cost incurred could be substantially higher as procurement was set to increase"[49].

The paddy MSP increase for the Kharif 2018-19 is the steepest ever in absolute terms at Rs 200 per quintal (12.9%), except that it was 21.0 % in the 2008-09 seasons. Also, the new MSP for tur is just 4.1% higher than last year's MSP (despite being 65.4% higher than A2+FL cost, i.e., Actual paid out cost plus the input value of family labor) against a year-on-year increase of 26% in 2008-09. Since the procurements have been limited to rice and wheat, the government's costs have been prevented from being flaring up to unmanageable levels.

The Government of India has announced a number of Farmer Friendly Initiatives in its 2018-19 Budget

All said, the Central government should not leave the farmers of Punjab to fend for themselves in their time of crisis as this state has always served as *India's breadbasket'*. They are expected to ensure Price stability, Marketing Facilities, Arrangement of the sale of their crops, Supply chain extension, Water –Saving Technologies, Liberal Loans at the reduced rates of interest and Subsidies and announce a policy of diversification of cropping pattern.

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IV. Conclusion

No doubt, Punjab is known as being the 'breadbasket' of India, but excepting a brief respite for about one and half decade during the 'Green Revolution' period (1967-78), the economic health of its beleaguered farming community continued to deteriorate as the agricultural debt swelled from Rs 57609 crores (576.09 billion) to Rs. 69355 crores (693. 55 billion) during the period: 2006-07 to 2014-15[50]. Fragmentation and small holdings of agricultural land, spending lavishly on social ceremonies, the sudden appreciation of the values of the agricultural land and produce made young generation of the farmers disinterested in the hard labor of farming and would depend upon the agricultural labor from U.P. and Bihar. There came a steep rise in the costs of agricultural implants, the wages of the laborers, the seeds, the tractors, diesel and the installment of tube wells because of depletion of groundwater level. Despite the bumper crops, the input cost of agriculture would far overweigh their earnings from the produce. There was 54% rural unemployed man-power. Both the Centre and the State governments did pretty little in easing the farmers out of this vicious cycle. Even during the Economic Liberalization period, Punjab did not benefit much because the emphasis was more on Secondary and Tertiary Sectors while the Agriculture sector of Punjab economy was neglected. The farmers were too stressed to commit suicides in thousands. The State Government have, now, agreed to waive off Rs.24000 crores of the debt of the farmers in phases while the Centre Government have raised the MSP ranging from 4.13-52.47% in case of 14 Rabi crops for 2018-19.

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After nomination of your institution as "Institutional Fellow" and constantly functioning successfully for one year, we can consider giving recognition to your institute to function as Regional/Zonal office on our behalf.
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The following entitlements are applicable to individual Fellows:



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Note :

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- In future, if the board feels the necessity to change any board member, the same can be done with the consent of the chairperson along with anyone board member without our approval.
- In case, the chairperson needs to be replaced then consent of 2/3rd board members are required and they are also required to jointly pass the resolution copy of which should be sent to us. In such case, it will be compulsory to obtain our approval before replacement.
- In case of "Difference of Opinion [if any]" among the Board members, our decision will be final and binding to everyone.

"

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Acknowledgments

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f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

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j) There should be brief acknowledgments.
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- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.



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Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

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- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
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- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
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Approach:

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Put figures and tables, appropriately numbered, in order at the end of the report.

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- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

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Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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