Online ISSN : 2249-4626
Print ISSN : 0975-5896
DOI : 10.17406/GJSFR

Global Journal

of Science Frontier Research: D

Agriculture & Veterinary



Adopting on-Farm Seed Priming Condition Effects on Germination

Highlights

Productivity Increment of Lentil Evidence from Nyamira and Bomet

Discovering Thoughts, Inventing Future

VOLUME 18 ISSUE 3 VERSION 1.0

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Volume 18 Issue 13 was originally issued as D3

Global Journal of Science Frontier Research: D
Agriculture & Veterinary

Volume 18 Issue 13
Originally issued as D3

Global Journal of Science Frontier Research: D
Agriculture & Veterinary

Volume 18 Issue 3 (Ver. 1.0)

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Contents of the Issue

i. Copyright Notice
ii. Editorial Board Members
iii. Chief Author and Dean
iv. Contents of the Issue

1. Influence of Different Drying Methods over the Biochemical Compositions of Japanese Quince. *1-4*
2. A Case Study of Localized Juvenile Onset of Canine Demodicosis in a Male German Shepherd Dog. *5-7*
3. Storage Container, Seed Moisture Level and Storage Condition Effects on Germination and Prevalence of Seed-Borne Fungi of Onion Seed. *9-16*
4. Response of Leek (*Allium ampeloprasum* var. *porrum* L.) Varieties to Plant Spacing at Boloso Bombe, Southern Ethiopia. *17-24*
5. Productivity Increment of Lentil Adopting on-Farm Seed Priming in Rainfed Hill Environment of Nepal. *25-31*
6. Evaluation and Demonstration of Potchefstroom Koekoek Chicken in and Around Mehoni areas of Southern Tigray Zone, Ethiopia. *33-41*
7. Technical Efficiency and its Determinants in Smallholder Tea Production: Evidence from Nyamira and Bomet Counties in Kenya. *43-54*

v. Fellows
vi. Auxiliary Memberships
vii. Preferred Author Guidelines
viii. Index

Global Journal of Science Frontier Research: D
Agriculture and Veterinary
Volume 18 Issue 3 Version 1.0 Year 2018
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Influence of Different Drying Methods over the Biochemical Compositions of Japanese Quince

By Teodora Mihova, Diyan Georgiev, Petya Ivanova & Boryana Brashlyanova
Research Institute of Mountain Stockbreeding and Agriculture

Abstract- The experiment was conducted in Cooperation between RIMSA-Troyan and FRDI-Plovdiv. The biochemical composition was analyzed in fresh fruits from selected (perspective) genotypes of Japanese quince. Changes in chemical indicators in dried fruits and their analogues were also studied. In order to achieve the aim, the following variants for drying of fruits were included in the experiment: by means of an alternative energy source, a heat pump, and indoor temperature. Chaenomeles fruits are characterized with low content of sugars, and relatively high amount of organic acids. The ascorbic acid amount reached up to 102 mg% in genotype 6'. There was a high content both of tanning substances - 0,542 % (genotype 1'), and pectin - 1.07% (genotype 6'). A significant increase of organic acids, tanning substances and pectin was reported in dried fruits from different variants of drying.

The aim includes a comparative analysis among variants for fruit drying with regard to the degree of retaining the biochemical composition indicators.

Keywords: chaenomeles sp., japanese quince, fruits, biochemical composition, drying technologies.

GJSFR-D Classification: FOR Code: 079999



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Influence of Different Drying Methods over the Biochemical Compositions of Japanese Quince

Teodora Mihova [α], Diyan Georgiev [σ], Petya Ivanova [ρ] & Boryana Brashlyanova [ω]

Abstract- The experiment was conducted in cooperation between RIMSA-Troyan and FRDI-Plovdiv. The biochemical composition was analyzed in fresh fruits from selected (perspective) genotypes of Japanese quince. Changes in chemical indicators in dried fruits and their analogues were also studied. In order to achieve the aim, the following variants for drying of fruits were included in the experiment: by means of an alternative energy source, a heat pump, and indoor temperature. Chaenomeles fruits are characterized with low content of sugars, and relatively high amount of organic acids. The ascorbic acid amount reached up to 102 mg% in genotype 6'. There was a high content both of tanning substances - 0,542 % (genotype 1'), and pectin - 1.07% (genotype 6'). A significant increase of organic acids, tanning substances and pectin was reported in dried fruits from different variants of drying.

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I. Introduction

Dried fruits from Chaenomeles sp. are used from thousands of years in Chinese medicine. The Ancient written information about this use of *Chaenomeles sp.* Lindl. as a drug was found in the book "Mingyi Bielu" by Tao Hongjing in the eastern literature for more than 1500 years ago (at about 500th D.C.) (Chace and Zhang, 1997; Yang Y., 2002). Japanese quince is a valuable remedy in China, and occupies a significant component of their prescriptions. The therapy is based on the ancient concept that acidic taste softens the liver (liver belongs to the element "tree") and thus relaxes the tendons, which are considered under the control of the hepatic system). (Yü and Kuan 1963; Anon. 1989; Chace and Zhang 1997; Yang Y., 2002).

Drying is a method that has been applied as a way to preserve fruits. The process includes different variants of application in order to obtain the finished product. It is opened, as it is being improved all the time in the different stages and elements of technology. An important element in the different drying technologies is to follow the changes in biochemical compositions of fruits (Morelló et al., 2003; Меженский, 2004; Мондешка, 2005; Graeme et al., 2007; Рупасова и др., 2008; Figueiredo, 2009; Zhu et al., 2012; Zhang et al. 2014).

Genus Chaenomeles is native in the the province Chongqing, China for hundreds of years, grown widely and is a traditional herb. Dried fruits in the form of dust are a dietary supplement used to prevent atherosclerosis and have antioxidant effects (Tang et al, 2000; Dharmananda; 2005; Malgorzata et al, 2007; Tang et al, 2010). In this connection, a method for the production of flours superfine powder with UF-250 airflow micronizer (Ka Chen et al., 2014).

It is very important to preserve the values of different biochemical indicators during the process. The influence of genotype and the respective drying technology for fruits is significant. These characteristics are important both for the qualities of a specific species, and for the suitability of the respective drying method. Different modes of the process lead to respective changes in the indicators of the biochemical composition of fruits. The temperature, humidity and duration of the process are essential. The fruit species is important to a great extent in order to determine the technology.

The aim is to follow the changes in biochemical composition of fruits under different drying technologies

II. Material and Methods

The experiment was conducted in cooperation between RIMSA-Troyan and FRDI-Plovdiv.

Selected genotypes of *Chaenomeles* genotypes the collection plantation of RIMSA were included. The following genetic types of *Chaenomeles* were included in the study: 1', 3' and 6'.

The drying process of fruits was conducted by means of:

I variant - heat pump
II variant - using alternative energy source
II variant - in a closed room with air circulation

The following indicators were studied: dry matter according to refractometer (Re%); sugars % (total, inverted and sucrose) according to the method of Schoorl and Regenbogen; Organic acids %; ascorbic acid according to method of Fialkov; tanning substances according to Levental method; pectin according to Melitz method. Analyses were conducted in the chemical laboratory of RIMSA.

Author α σ: Research Institute of Mountain Stockbreeding and Agriculture- Troyan, Bulgaria, 5600 Troyan, Vasil Levsky Str., 281.
e-mail: teodora.mihova@gmail.com
Author ρ ω: Food Research and Development Institute – Plovdiv, Bulgaria, 4000 Plovdiv, Vasil Aprilov Str. 154.

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Data were mathematically processed by means of two-factor analysis of variance. For assessment of differences was used LSD indicator (Lidanski, 1988).

III. Results and Discussion

Chaenomeles fruits have higher values for some of the biochemical indicators, and for others they are lower in comparison with fruit of other tree species. There is a difference in the biochemical composition of the final product of different genotypes to methods of drying. Similar studies of various methods of drying the fruit and vegetables have been conducted by Sagar and Kumar (2010). They describe in detail the influence of drying the quality of products.

For selected genetic types, dry matter in fresh fruits has insignificant differences, which are within the intervals from 7% (genotype 6') to 8.5% (for the other two genotypes) (Table 1). Differences in dry weight matter were more significant. For genotype 6' it was 10.39%, and it was the highest in genotype 1' - 12.52%.

Content of sugars was low, which is characteristic for that species. Total sugars for the three genotypes were within the range of 4-5%. Disaccharides were presented in lower amount for genotype 3'- 2.7 %, they were higher for genotype 6'- 3.05 % and genotype 1'- 3.55 %. Sucrose content was in small amount for genotype 1' and 6'- 0.76 %, and about two times more for genotype 3'- 1.9 % Organic acids were in optimal values for that fruit tree species. They were almost the same for the three genotypes within the range 2.14% - 2.41 % Ascorbic acid was an indicator with high values for Chaenomeles fruits. It reached up to 102.08 mg/% for genotype 6'.

Tanning substances, which largely determine the tart taste of fruits, varied within the range from 0.354 % (genotype 3') to 0.542 % (genotype 1'). According to Mondeshka (2005) Japanese quince is a valuable source of phenolic compounds (500 mg / 100 g), and anthocyanins and leykoantotsianins (greater than 700 mg / 100 g), K (85,5), Ca (22,7), Mg (12 , 0), P (27,4). It also contains Fe, Mn, Al, small amounts of Cu, Zn, B, Na and Sr, but the most valuable is the high content of vitamin C in fruit - 124-182 mg per 100 g of fruit.

Pectin is the other indicator where was reported a significant variation of values among genotypes. It was the lowest for genotype 3'-0.37 % and higher for genetic types 1' and 6', respectively 0.98% and 1.07 %. Рупасова и др.(2008) investigated the biochemical composition of different genotypes and varieties of Japanese quince.

Dry weight matter in dried fruit for the three variants was within values from 80% to approximately 91%. That indicator was the highest for fruits dried in heat pump. For the other two drying methods, values were almost identical with the exception of genotype 6' of the third variant, where it was the lowest - 80.92%. The results show that the drying process was completed in a normal way (Table 1).

There was a significant variation of sugar content as a whole. The values of total sugars were much higher in heat pump drying, which varied in the intervals 12.6% - 15.35%. They were lower for the other two variants. There is a significant difference between genotype 1' and the other two for all the three variants. The values of genotype 1' were the lowest for the third one - 3.55%. Drying method has an influence over the indicator. Differences among the first and the other two drying variants were mathematically proven ($P<0.05$) (Table 2).

The results were analogous in relation to the other indicator - inverted sugar. It reached values from 12.1% for genotype 3' in the first variant. They were a few times less for genotype 1' than the alternative energy source and in a closed room with air circulation, respectively - 4.7% and 2.7%. Differences were very well proved between the first and third variant ($P<0.001$).

Table 1: Biochemical composition of chaenomeles fruits in different drying variants

Drying variants	Genotype	DM in %	Dry weight	Total sugars %	Inverted sugar %	Sucrose %	Acids %	Ascorbic acid mg/%	Tannins %	Pectin %
Fresh	1'	8.5	12.52	4.35	3.55	0.76	2.21	96.80	0.542	0.98
	3'	8.5	11.71	4.70	2.70	1.90	2.41	88.00	0.354	0.37
	6'	7.0	10.39	3.85	3.05	0.76	2.14	102.08	0.400	1.07
Heat pump	1'		90.84	12.45	10.75	1.62	9.67	49.28	0.896	0.13
	3'		90.74	15.35	12.10	3.09	10.59	24.16	0.990	0.20
	6'		89.69	12.60	11.10	1.43	10.53	49.28	1.179	4.17
Sun dryer	1'		87.82	5.70	4.70	0.95	10.25	31.68	0.802	3.61
	3'		86.71	8.55	8.55	0.0	10.45	22.88	0.377	2.84
	6'		90.04	8.55	8.55	0.0	10.05	35.20	0.684	3.11
In a closed room	1'		86.64	3.55	2.70	0.81	9.85	19.36	0.684	2.29
	3'		86.62	6.85	6.35	0.48	10.39	19.36	0.707	1.30
	6'		80.92	8.55	8.55	0.0	10.18	22.88	0.802	2.43

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Table 2: Significance of factors influencing the values of qualitative indicators of Chaenomeles fruits

Indicators	DM in %	Dry weight	Total sugars %	Inverted sugar %	Sucrose %	Acids %	Ascorbic acid mg/%	Tannins %	Pectin %
Genotypes	NS	NS	NS	NS	NS	NS	NS	NS	NS
Different methods of drying	NS	NS	P<0.05	P<0.01	P<0.05	NS	P<0.05	P<0.06	NS
LSD	-	-	3,07	5,4	1,46	-	15,61	-	-

Sucrose amount was the highest for genotype 3' in the first variant - 3.09%. Calculated in relation to absolute dry matter, the decrease in comparison with fresh fruits was 6.6 times. For the other two variants sucrose had lower values, and for some genetic types it was completely missing. There were proven differences for that indicator in drying technologies between the first and the other two variants (P<0.05).

The increase of organic acids was approximately five times in dried fruits in comparison with fresh ones. There were no significant values for forms of the different genetic types. The values of that indicator were within the range from 9.67% (genotype 1') to 10.53 % (genotype 6').

In regard to biologically-active substance of ascorbic acid, the decrease was dramatically in dry fruits in comparison with fresh. The decrease was approximately five times in dried products. Probably that was due to the oxidation process in fruits during storage period. The highest values were recorded for genotype 1'and 6' in the first variant - 49.28 mg/%. The lowest values were observed for genotypes 1' and 3' in the third variant. Probably, the amount of ascorbic acid is influenced by drying technologies of fruits.

There was a significant increase of tanning substances in dried fruits for some genotypes. For genotype 6' in the first variant they reached values up to 1.179 %, which is 2.9 times more than content in fresh fruits. Recalculated to absolute dry matter the decrease was 4.4 times in the dried product. Variability of that indicator was within wide limits for genotypes in different variants. The lowest values were recorded for genotype 3'- 0.377 % in the alternative energy source variant. The decrease towards dry units was 9.7 times. There is a tendency of influence of the drying method over values of tanning substances.

There was a significant variability in pectin values in different variants. It is worth noting its amount for genotypes 1' and 3' respectively: 0.13 % and 0.2 % in heat pump drying variant. For first genotype the decrease in fresh fruits was 7.5 times and for second one it was 1.9 times. The highest values of that indicator were recorded for genotype 6' of all variants, as in the first one the pectin amount reached up to 4.17 %. Its decrease towards dry units was 3.3 times. As a complex assessment for the three genotypes, in relation to higher pectin values, the drying variant of the alternative energy source could be determined.

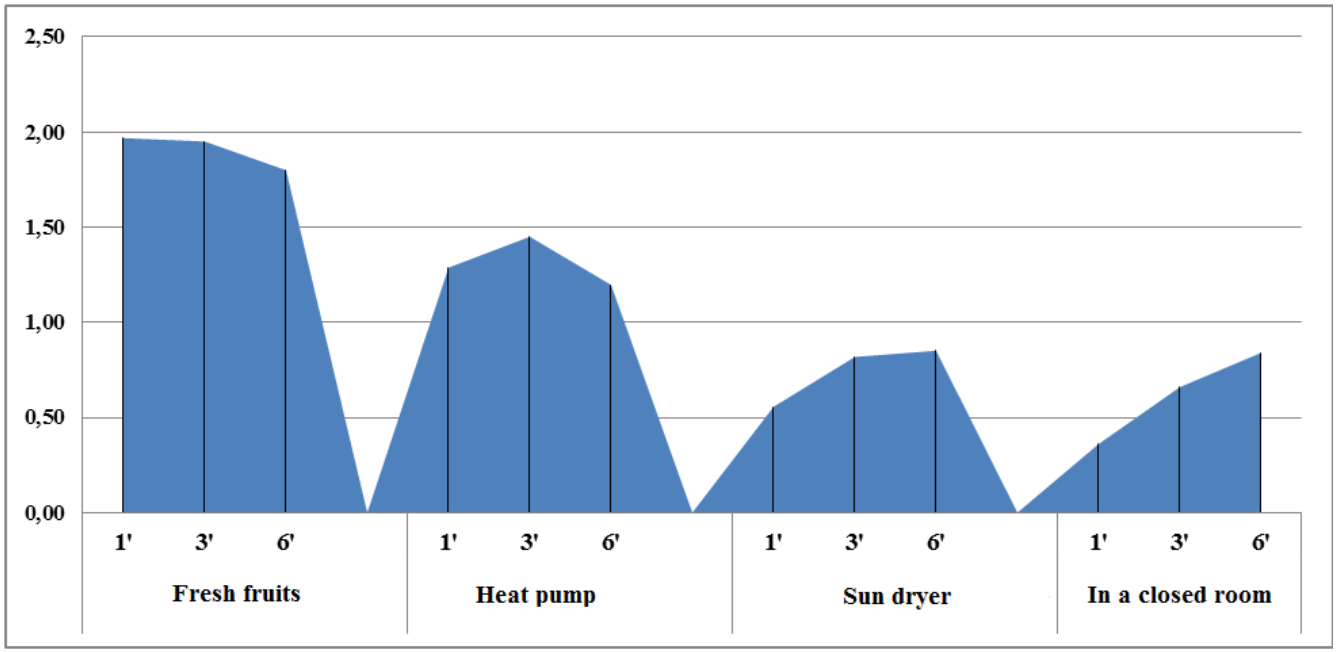

Figure 1: Acidometric coefficient of chaenomeles fruits in different drying variants

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Sugar-acid coefficient in fresh fruits reached values up to 1.97 % (genotype 1'). For the other two genotypes it was in close ranges. In the heat pump drying variant, values were closest to fresh fruits, which were in the interval 1.20% (gen. 6') – 1.45 % (gen. 3'). Significantly lower were for the other two methods (Figure 1).

IV. Conclusion

A complex assessment was made to different drying variants of fruit drying of some perspective *Chaenomeles* genotypes.

The influence of different drying methods of *Chaenomeles* genotypes over their biochemical composition was studied.

It was found that sugars and ascorbic acid of the three genotypes were better preserved in heat pump drying variant.

Some regularities were reported of higher values for some indicators of genotypes from different drying variants.

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Global Journal of Science Frontier Research: D
Agriculture and Veterinary
Volume 18 Issue 3 Version 1.0 Year 2018
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

A Case Study of Localized Juvenile Onset of Canine Demodicosis in a Male German Shepherd Dog

By Bharata Regmi & Bablu Thakur
Agriculture and Forestry University

Abstract- A ten-month old male German shepherd dog, named Tony was presented to the Himalayan Animal Rescue Trust (HART), Pokhara with the history of alopecia, itching, scratching and erythema over the facial region. Toney weighed 36 Kg, was black and brown in color. On clinical examination, the mucous membrane was found to be pink, and the body temperature was normal. The eczematous lesion was erythematous and alopecia in the area surrounding the lesions. The case was suspected of parasitic skin infection, and three deep skin scrapping were taken with the help of scalpel blade after moistening the skin with paraffin oil. The scraping was treated with few drops of KOH. The scab and matted hair were detached with the help of a clean needle. The sample was placed on a clean and dry microscopic glass slide and heated gently to soften the scab and clear the debris. A cover slip was placed, and it was examined first under the low power then high power for detail study. The larva and nymph of Demodex Canis were observed under the microscopic examination. The case was diagnosed as a localized juvenile onset of canine demodicosis.

Keywords: *localized, juvenile, demodicosis, skin scrapings.*

GJSFR-D Classification: *FOR Code: 070799p*



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Bharata Regmi [α] & Bablu Thakur [σ]

Abstract- A ten-month old male German shepherd dog, named Tony was presented to the Himalayan Animal Rescue Trust (HART), Pokhara with the history of alopecia, itching, scratching and erythema over the facial region. Toney weighed 36 Kg, was black and brown in color. On clinical examination, the mucous membrane was found to be pink, and the body temperature was normal. The eczematous lesion was erythematous and alopecia in the area surrounding the lesions. The case was suspected of parasitic skin infection, and three deep skin scrapping were taken with the help of scalpel blade after moistening the skin with paraffin oil. The scraping was treated with few drops of KOH. The scab and matted hair were detached with the help of a clean needle. The sample was placed on a clean and dry microscopic glass slide and heated gently to soften the scab and clear the debris. A cover slip was placed, and it was examined first under the low power then high power for detail study. The larva and nymph of *Demodex Canis* were observed under the microscopic examination. The case was diagnosed as a localized juvenile onset of canine demodicosis. The lesions were cleaned with chlorhexidine gluconate solution followed by topical application of benzoyl peroxide and systemic administration of ivermectin, cimicoxib and amitraz bathing. The treatment continued till two subsequent microscopic examinations of skin scrapping showed negative result. The dog recovered uneventfully and looked quite healthy and normal again.

Keywords: localized, juvenile, demodicosis, skin scrapings.

I. Introduction

Canine demodicosis is a common, non-contagious, inflammatory parasitic dermatosis characterized by excessive proliferation of the commensal mite *Demodex canis* within the hair follicles and sebaceous glands (Verde, 2005) and typically leads to alopecia, comedones, follicular papules and pustules, scaling and crusting (Mueller, 2012). According to the extent of the disease, canine demodicosis can be classified as localized or generalized, as the course and prognosis of the two types of demodicosis are vastly different (Verde, 2005). Localized demodicosis is usually limited to the face and occasionally extremities of immature dogs and involves five or fewer areas. The clinical signs include focal areas of alopecia and erythema on the face, head or legs. Typically both types of demodicosis start during puppyhood (3 to 18 months), but adult onset demodicosis (AOD) can also occur. The AOD is a generalized demodicosis even more difficult to treat than juvenile demodicosis. Demodex mites are considered to be a normal part of the cutaneous microfauna in the dog and are transmitted from the bitch to the pups during the first days of life. Puppies raised in isolation after caesarean section does not have any Demodex mites. It is assumed that immune suppression or a defect in the skin immune system allows for mites to proliferate in hair follicles, resulting in clinical signs. In young animals, endoparasitism, malnutrition and debilitation may lead to an immune compromized state that favors mite proliferation and development of skin disease. In adult animals, chemotherapy, neoplasms, hypothyroidism or hyperadrenocorticism, for example, may suppress the immune system sufficiently to trigger proliferation of the mites. However, studies proving a cause-effect relationship between these factors and demodicosis are lacking. Many immunosuppressed dogs never develop demodicosis, and in many cases an underlying cause may not be found (Mueller et al.2012). Most localized infections resolve on their own immunity and do not require generalized therapy. They may be treated topically with daily applications of benzoyl peroxide rubbed in the direction of the hair growth. If the lesions have spread or you see a high ratio of immature to mature mites, proceed with generalized therapy (Rutan, 2006). There are three methods for treating generalized mange: amitraz dips, oral ivermectin or milbemycin. Prognosis for localized demodicosis in puppy is good, especially if lesions resolve without treatment but variable to guarded for the generalized juvenile demodicosis (Moriello, 2011).

II. Case History and Clinical Signs

A male German shepherd dog named Tony of ten months was presented to the HART clinic as an outpatient when the treatment with para-vet became unsuccessful. The dog was of black and brown color weighing 36 kg with the Body condition score (BCS) 3 and skin condition score (SCS) of 1.5. The clinical signs were facial alopecia and erythema (figure-1). The

Author α σ: M. V. Sc, Surgery & Radiology, Agriculture and Forestry University (AFU), Rampur, Chitwan, Nepal.
e-mail: regmibharat2008@gmail.com

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mucous membrane was pink and the body temperature was normal.



Figure 1: Facial alopecia and erythematous lesions

III. Methodology

The most severely affected three parts were selected and moistened with paraffin oil for sampling. The lesions on the skin were pressed with thumb and index finger of left hand, and the skin was scrapped with the right hand using a scalpel dipped in mineral oil. The deep skin scrapings were taken from three different lesions until the blood oozes out. The sample on a clean and dry glass slide was treated with few drop of 10% KOH, then macerated with scalpel to make a thin smear and covered with cover slip. Finally, the slide was placed under low power microscope and then shifted to high power to observe for the details of skin parasites (figure-2). The test was repeated again in next follow up after a week until the two consequent scrapings test become negative.

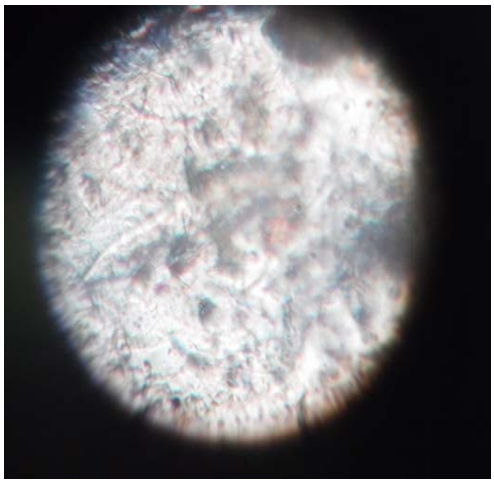

Figure 2: Nymphal stages of *Demodex canis* under microscopic examination

IV. Differential Diagnosis

Generalized pyoderma, folliculitis, dermatophytosis, muzzle furunculosis, canine impetigo, contact dermatitis, pemphigus complex, lupus erythematosus and dermatomyositis (Verde, 2005).

Diagnosis

Localized juvenile onset of canine demodicosis

V. Treatment

The benzoyl peroxide gel and chlorhexidine gluconate-2% were prescribed for one week. The chlorohexidine was prescribed for cleaning the lesions and then the gel suggested for applying on the lesions after cleaning every two times a day. In addition, following medicines were prescribed until the two tests show negative result;

1. Amitraz, 12.5%
   Sig: 2 ml / lit. Water, bathing x every 7 days
2. Ivermectin, 10 mg
   Sig: 1 tab, OD, orally
3. Cimicoxib, 80 mg
   Sig: 1 tab, OD, orally for 5 days

VI. Result and Discussion

Finally, the dog was found to be recovered after three weeks of treatment when the two consequent skin scrapping test was found negative on microscopic examination (figure-3). The localized form usually heals spontaneously in two months. It should not to be treated with acaricides. Benzoyl peroxide gel to massage into alopecic areas once a day, rubbing in the direction of the hair growth could be indicated (Verde, 2005). In approximately 10% of the cases, evolution towards generalized form is unavoidable, whether or not an acaricidal therapy had been initiated and the lesions may become larger (Rutan, 2006; Verde, 2005). In this case, the clinician also tried the topical treatment but did not provide satisfactory result on the appearance of lesion. The load of parasites seen under the microscope may be due to the evolution into the generalized form.



Figure 3: Recovery from the demodicosis

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Amitraz may not be safe for all dogs and may cause sedation, allergy. Oral ingestion of amitraz may result in vomiting, ataxia, hypothermia, reduced gut motility, hyperglycemia, seizures, bradycardia and central nervous system depression or coma. So, it should be used judiciously. Similarly, ivermectin should not be used on Collies or herding breeds such as Shetland Sheepdogs, Old English Sheepdogs and Australian Shepherds. Neurotoxicity may develop due to overdose or long-term use of ivermectin. Therefore, it should be used cautiously and stop after finding no parasites on the test of skin scrapings.

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Global Journal of Science Frontier Research (D) Volume XVIII Issue III Version I Year 2018
8

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Global Journal of Science Frontier Research: D
Agriculture and Veterinary
Volume 18 Issue 3 Version 1.0 Year 2018
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Storage Container, Seed Moisture Level and Storage Condition Effects on Germination and Prevalence of Seed-Borne Fungi of Onion Seed

By Abu Ashraf Khan, Kabir Uddin Sarker, M. Moynul Haque, M. Tanbir Rubayet & Ismail Hossain Mian

Bangabandhu Sheikh Mujibur Rahman Agricultural University

Abstract- Laboratory experiments were conducted to evaluate the effects of storage containers (aluminum foil bag, polythene bag, plastic container, metal container and earthen pot), seed moisture level (5, 7, and 9%) and storage conditions (ambient temperature 30 ± 2o C, refrigerator 8 ± 1o C and dehumidified condition 20o C and RH at 40%) on germination and prevalence of seed-borne fungi of onion seed over a period of 170 days. Among the storage containers aluminum foil bag, polythene bag and plastic container performed better on germination and prevalence of seed-borne fungi of seeds. Seeds maintained high germination and lower seed-borne fungi when stored with 5 and 7% initial moisture. Considering storage conditions, refrigerator and dehumidified storage performed better. In two way interaction of container and seed moisture level, the highest germination and lowest seed-borne fungal infection was recorded in seeds stored in aluminum foil bag with 7% moisture content.

Keywords: storage container, seed moisture content, storage condition, germination, seed-borne fungi, onion seed.

GJSFR-D Classification: FOR Code: 060704



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Storage Container, Seed Moisture Level and Storage Condition Effects on Germination and Prevalence of Seed-Borne Fungi of Onion Seed

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Abstract- Laboratory experiments were conducted to evaluate the effects of storage containers (aluminum foil bag, polythene bag, plastic container, metal container and earthen pot), seed moisture level (5, 7, and 9%) and storage conditions (ambient temperature 30 ± 2° C, refrigerator 8 ± 1° C and dehumidified condition 20° C and RH at 40%) on germination and prevalence of seed-borne fungi of onion seed over a period of 170 days. Among the storage containers aluminum foil bag, polythene bag and plastic container performed better on germination and prevalence of seed-borne fungi of seeds. Seeds maintained high germination and lower seed-borne fungi when stored with 5 and 7% initial moisture. Considering storage conditions, refrigerator and dehumidified storage performed better. In two way interaction of container and seed moisture level, the highest germination and lowest seed-borne fungal infection was recorded in seeds stored in aluminum foil bag with 7% moisture content. In case of storage container and storage condition the highest germination and lowest prevalence of seed-borne fungi was recorded in seeds stored in aluminum foil bag in refrigerator, while in moisture level and storage condition better quality was maintained in seeds with 7% moisture level stored in refrigerator. From the results of the present experiment, it is suggested that onion seeds may be stored in sealed container and cool condition. The initial moisture content of seed should also be minimum (5 to 7%) for maintaining good quality and health of onion seeds.

Keywords: storage container, seed moisture content, storage condition, germination, seed-borne fungi, onion seed.

I. Introduction

Onion (*Allium cepa* L.) belonging to the family Alliaceae is an important spice and popularly used as condiments for flavoring a number of foods (Vohra *et al*., 1974). As demand of onion is increasing, production of onion needs to increase in order to meet the requirement in the years to come. There exist enormous scope to increase the productivity of onion of which the most important one is the availability and use of good quality seed having high germination capacity and health status (Kant *et al*., 1999). Seed is the basic and essential input for any crop production. High quality seed is a critical input on which all other inputs will depend for their full effectiveness (Thompson, 1979). In majority of the Asian countries, particularly in Bangladesh most of the onion seeds used comes from farmers' saved sources which are badly infected by fungi with very poor germination. A good quality seed may also be seriously deteriorated if it is stored under suboptimal condition. Poor storage condition gives rise to deterioration of seed quality and the resultant loss of viability. But the farmers are ignorant about modern technologies of seed storage. They store seeds traditionally in various types of containers such as earthen pots, bamboo container, gunny bag or plastic bags during the wet monsoon period after harvest. Seeds stored in such types of containers are prone to invasion by storage fungi. Preservation of onion seeds is a major problem in Bangladesh. Storage period is more than six months (April to October) before sowing in the next season. Unfortunately high rainfall, high humidity and high temperature prevail in this period causing detrimental effect to the seed viability. As a result seeds absorb moisture from atmosphere and these containers are not suitable to protect seeds from microbial infestation. The seeds store in ordinary containers absorbs moisture from the environment and subsequently loses their viability quickly and deteriorates germination percentage and reduces seedling vigor (Hossain, 1978).

The factors affecting onion seeds longevity in store had been quantified by Ellis and Roberts (1981). The percentage of viability of onion seed after a period of storage depends on the initial viability, the seed moisture content and the storage temperature. According to Usberti and Gomes (1998) seed viability deterioration rate depends on the storage condition which includes temperature, relative humidity, seed

Author α ω ¥: Department of Plant Pathology, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur 1706, Bangladesh.
e-mails: ashraf@bsmrau.edu.bd, tanbir86plp@gmail.com, ihmian2007@gmail.com
Author σ: Seed Certification Agency, Gazipur 1701, Bangladesh.
e-mail: dsco.narsingdi@gmail.com
Author ρ: Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur 1706, Bangladesh.
e-mail: moynul160@yahoo.com

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moisture levels and storage containers. Onion seeds lose viability at a faster rate than seeds of most other vegetables. Obviously under less favorable storage condition, the seeds will show still poorer storability. It is difficult to maintain good seed viability for more than a year under ambient condition in unsealed containers. Seeds stored in air tight containers after proper drying the problem of vigor and viability could be considerably reduced (Islam *et al*., 2013).

Storage temperature and relative humidity as well as seed moisture levels are most important for prevalence of fungi in seeds. Growth of storage fungi enhance in high temperature and relative humidity in storage and initial high moisture content of seeds (Neergaard, 1979). *Aspergillus* spp. *Penecillium* spp. and *Fusarium* spp. can cause losses of onion seeds in storage (Gupta *et al*., 1984; Fakir, 2001). Storage fungi also play an important role in reducing quality of seeds in storage. They bring down germinability, discoloration of the seed, biochemical changes, accumulation of toxins and loss in weight (Neergaard, 1979). Storage life of seeds could be maintained over a longer period by using proper packaging materials and better environment (Roknuzzaman *et al*., 2008; Khalequzzaman *et al*. 2012; Lambat *et al*., 2015; Mollah *et al*., 2016). Therefore, the experiment was conducted to evaluate the effects of different storage containers, seed moisture levels and storage conditions on seed germination and prevalence of seed-borne fungi of onion seed.

II. Materials and Methods

Three independent laboratory experiments were conducted to investigate the effect of seed containers and seed moisture level, seed containers and storage conditions, and seed moisture level and storage conditions on seed germination and prevalence of seed-borne fungi of onion. Freshly harvested onion seeds attained three moisture levels of 5, 7, and 9% were kept in five storage containers. Five storage containers were aluminum foil bag, polythene bag, metal container, plastic container and earthen pot. The seeds were stored in three storage conditions such as ambient temperature, refrigerator and dehumidified conditions. The ambient temperature during storage period was recorded (30 ± 2° C). The refrigerator temperature was maintained 8 ± 1° C. The temperature was maintained at 20° C in dehumidified storage with 40% relative humidity. The experiments were laid out at completely randomized design. The seeds were stored for 170 days (one season, after harvest to next sowing season). Data on seed germination and prevalence of seed-borne fungi were recorded just prior to storage (0 days), 70 days after storage (DAS) and 140 DAS following standard methods.

Germination: Four hundred seeds were randomly taken from each sample for germination test. Three layered moistened blotter paper was placed on germination petri-dishes. Hundred seeds were used on each petri-dish and kept at 25°C temperature for 12 days for germination. Seedlings were counted every day up to the completion of germination at 12 day. Only the normal seedling was counted for calculating the germination percentage (ISTA, 1996).

Prevalence of seed-borne fungi: Seed-borne pathogens associated with the onion seed sample was determined by blotter method (ISTA, 1996). In this method, three layers of blotter papers (Whatman No. 1) were soaked in sterilized water and placed in the bottom of the 9 cm diameter Pyrex glass Petridish. Four hundred seeds from each sample were taken randomly and then placed on the moist blotter paper at the rate of 25 seeds per plate. The petri dishes with seeds were then incubated at 25±2° C temperature, 12/12 hours alternating cycles of NUV light and darkness for seven days. After incubation, the seeds were examined under steriobinocular microscope for the presence of seed-borne fungal pathogens and identified by observing their growth characters. In case of confusion, temporary slide was prepared and examined under a compound microscope and identified using appropriate keys (Mathur and Kongsdal, 2003). Results were expressed in percentage of seeds infected by the seed-borne pathogens.

III. Results

a) *Independent effect of storage container, seed moisture level and storage condition on seed germination*

Significant variations were observed in germination percentage due to the effects of different storage containers, seed moisture levels and storage conditions at 70 and 140 days after storage (DAS). The germination percentage decreased with the increase in storage period from 0 to 140 days. At 140 DAS the highest germination (74%) was obtained from the seeds stored in aluminum foil bag which was statistically similar with the seeds stored in plastic container (72%) and polythene bag (71%). The significantly lowest germination (60%) was obtained from seeds stored in earthen pot. The seeds which were stored with 7% moisture level had the highest germination (75%), whereas the seed stored with 5% and 9% moisture content had 73% and 57% germination, respectively at 140 DAS. Germination percentage with 5% and 7% moisture level was significantly similar. At 140 DAS, the highest germination percentage (70%) was recorded from seeds stored in a refrigerator and dehumidifier, whereas the significantly lowest germination percentage (65%) was obtained from seeds stored at ambient condition (Fig. 1).

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b) *Independent effect of storage container, seed moisture level and storage condition on prevalence of seed-borne fungi*

The seed-borne fungal population increased with increase in storage period. Significant effects of storage containers, seed moisture levels and storage conditions were observed on prevalence of seed-borne fungi at 70 and 140 days after storage (DAS) (Fig. 2). At 140 DAS the lowest infection of fungi was recorded when the seeds were stored in aluminum foil (6.40%) which was statistically similar with the seeds stored in polythene bag (6.44%) and plastic container (6.75%). The significantly highest fungal population (9.69%) was recorded in seeds which were stored in earthen pot followed by metal container (7.25%). Seed-borne infection was increased with the increase of initial moisture level of seeds. The seeds containing 7% moisture yielded the significantly lowest prevalence of fungi (6.95%) followed by 5% moisture level (6.97%) but seeds containing 9% moisture had significantly highest (8.00%) prevalence of seed-borne fungi at 140 DAS. Considering storage conditions, the lowest prevalence of fungi at 140 DAS was observed in seeds stored in refrigerator (5.98%) which was statistically similar with dehumidified condition (6.12%) whereas significantly the highest prevalence of seed-borne fungi (9.80%) was recorded in seeds in ambient condition.

c) *Interaction effect of storage container and seed moisture level on germination and prevalence of seed-borne fungi*

The seeds which were tested at 70 and 140 DAS, the germination percentage varied significantly in different types of storage containers with various seed moisture levels. The germination percentage of seed gradually decreased with increase in storage period. At 140 DAS, the highest germination was obtained from seeds which were stored in aluminum foil bag with 7% initial moisture content (82%) followed by polythene bag with 5 and 7% moisture content (81%). The lowest germination was recorded from seeds having 9% initial moisture content and stored in earthen pot (50%) followed by polythene bag (56%) with same moisture level (Table 1). Table 1 also showed that the highest fungal prevalence was recorded at 140 DAS in earthen pot (10.42%) with 9% moisture content followed by earthen pot 9.33% and 9.25% with 7% and 5% moisture content, polythene bag (7.83%), aluminum foil bag and plastic container (7.67%) and metal container (7.42%) with 9% moisture content. The lowest fungal incidence was recorded in seeds stored in aluminum foil bag with 7% moisture content (5.50%), followed by polythene bag with 7% moisture content (5.58%).

d) *Interaction effect of storage container and storage condition on germination and prevalence of seed-borne fungi*

At 140 DAS, the seed stored in aluminum foil bag in refrigerator gave the highest germination (77%) followed by in aluminum foil bag in dehumidified condition (75%) and plastic container in dehumidified condition (74%) and plastic container in refrigerator (73%). Polythene bag under dehumidified and refrigerator (72%) also showed better performance. The lowest germination of seeds was recorded from earthen pot under ambient condition (57%) (Table 2). Significantly the highest prevalence of seed-borne fungi was recorded at 140 DAS in earthen pot in ambient condition (12.58%) followed by metal container with ambient storage condition (10.67%). The lowest prevalence of fungi was recorded in seeds stored in aluminum foil bag in refrigerator (5.08%) followed by aluminum foil bag and plastic container in dehumidified storage conditions (5.25%) (Table 2).

e) *Interaction effect of moisture content and storage condition on germination and prevalence of seed-borne fungi*

Significant variation was observed in germination in seeds with various moisture level and storage condition at 70 and 140 DAS. At 140 DAS, the highest germination (76%) was recorded in seeds stored in refrigerator with 7% moisture content followed by refrigerator with 5% moisture content (75%), dehumidified conditions (74%) with both 7% and 5% moisture content. The lowest germination was recorded in seeds in ambient condition with 9% moisture content (50%) which was followed by dehumidified storage condition with same moisture content (60%) (Table 3).

The highest prevalence of fungi was recorded in seeds stored in ambient condition with 9% moisture content (10.80%) followed by 9.50 and 9.10% at 5 and 7% seed moisture content also in ambient condition, respectively. The lowest prevalence was found in seeds with 7% moisture content stored in refrigerator (5.55%) followed by dehumidified (5.65%) and refrigerator (5.75%) at 5% moisture content (Table 3).

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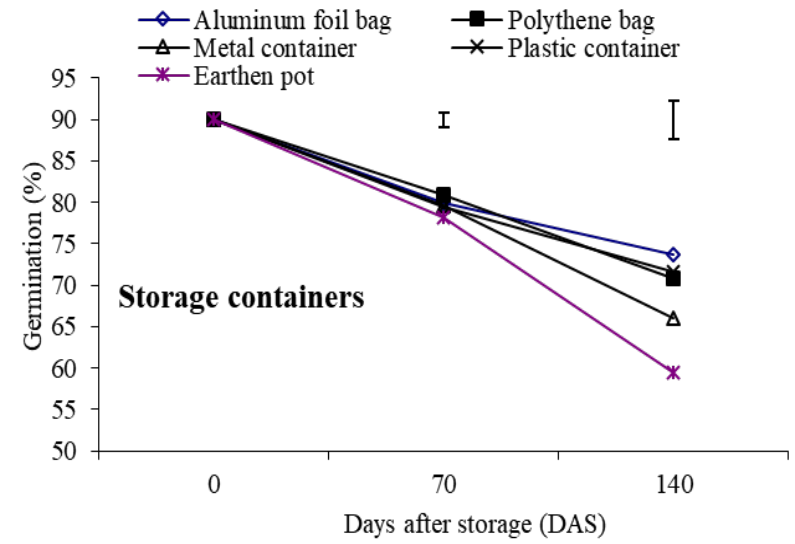

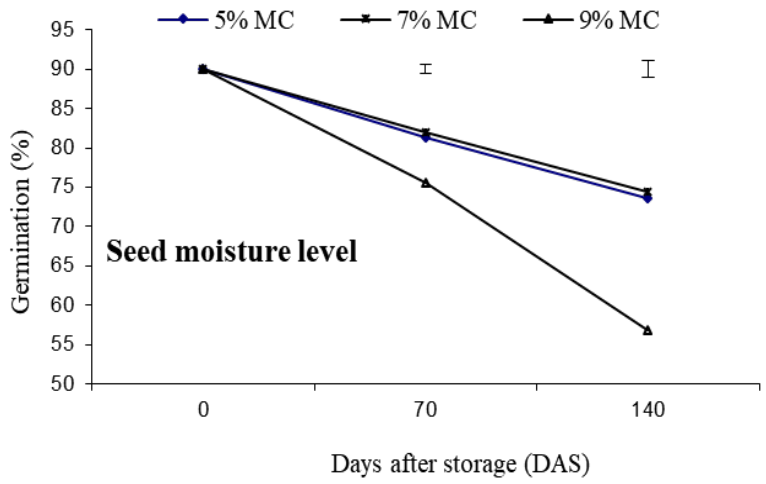

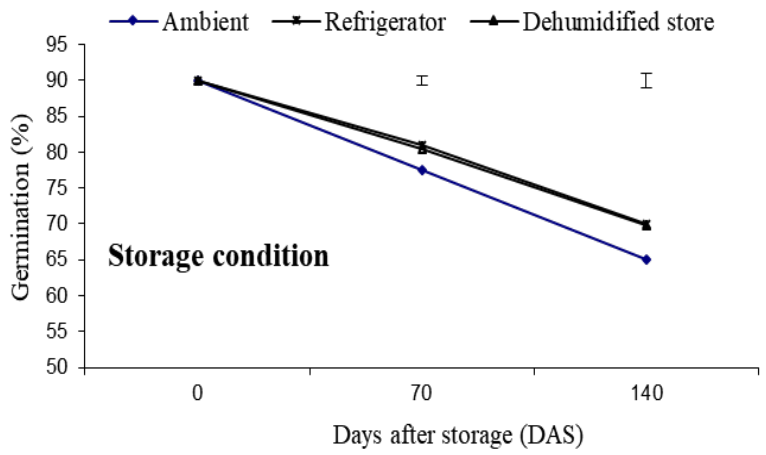

Fig. 1: Effect of storage container, seed moisture level and storage condition on germination of onion seed. Vertical bar indicates LSD $_{(0.05)}$ value

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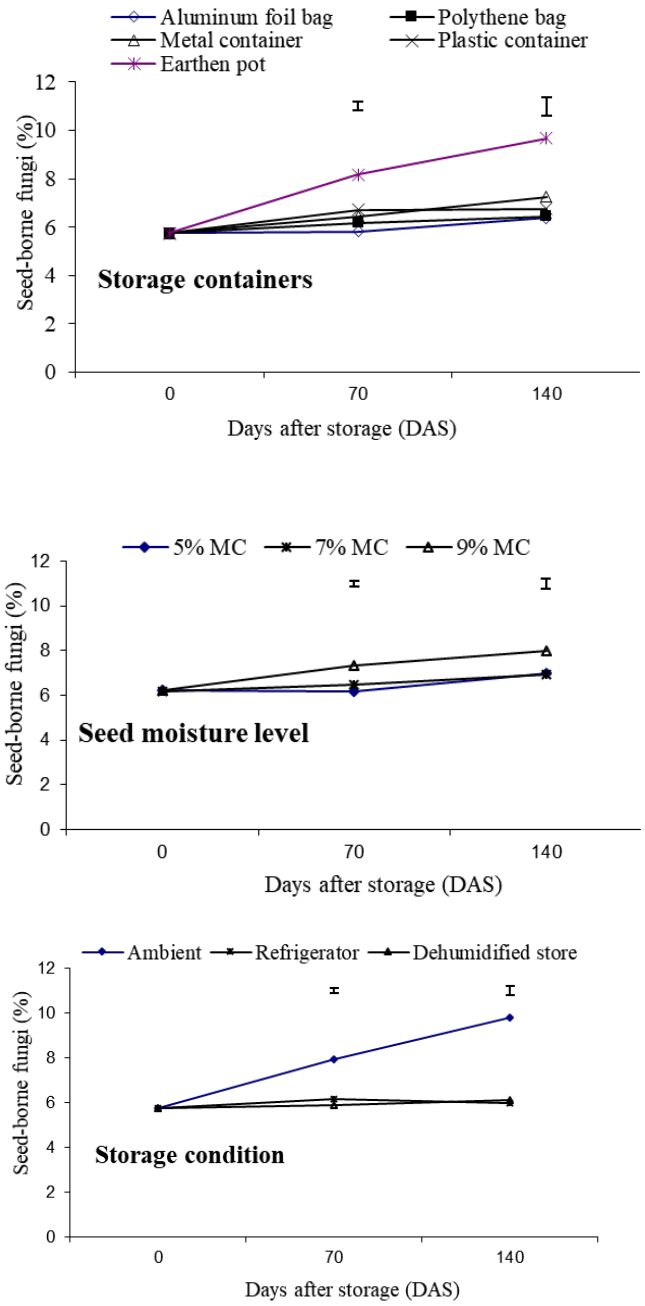

Fig. 2: Effect of storage container, seed moisture level and storage condition on prevalence of seed-borne fungi of onion seed. Vertical bar indicates LSD $_{(0.05)}$ value

IV. Discussion

Quality of seeds in respect of germination and prevalence of seed-borne fungi were studied in the experiment by using five different types of storage containers, three seed moisture levels and three different storage conditions. Results suggested that storage containers, seed moisture levels and storage conditions play an important role on seed germination and infection of seed-borne fungi. Among the five containers germination loss and infection of seed-borne fungi was lower when the seeds were stored in sealed container like aluminum foil bag, polythene bag and plastic container. On the other hand, seed stored in earthen pot yielded higher fungal infection and lower germination. In ambient condition, air tight containers gave better results than purported containers of which aluminum foil bag was the best followed by polythene bag and plastic container. In contrast, earthen pot showed the lowest performance in respect of germination percentage and seed-borne fungi under ambient condition as a purported container. This type container affects moisture absorbance and deteriorated seed quality during storage of seeds. The rate of moisture absorbance was higher in earthen pot. Higher moisture content in the seed is the main reason of quick

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deterioration of seed quality in earthen pot. Higher germination and lower prevalence of fungi were also reported in sealed container by other authors (Rahman and Rahman 1997; Roknuzzaman *et al*., 2008; Khalequzzaman *et al*. 2012; Lambat *et al*., 2015; Mollah *et al*., 2016; Sultana *et al*., 2016). Ellis and Roberts (1981) suggested that commercial onion seed may be dried to about 6.3% moisture content and sealed into moisture proof cans or foil packets. They also observed that in these conditions onion seed could remain fully viable for at best three years. Charjan and Tarar (1992) reported that seeds stored in polythene bags germinated better and had less fungal contamination than that stored in cloth bags. Seeds when stored with 5 and 7% seed moisture content maintained good germination. The seed quality deteriorated drastically when seeds stored with 9% seed moisture content. The incidence of fungi was also lower in seeds stored with lower moisture content (5% and 7%). It reveals that lower moisture content of seeds decreases fungal activity. Results suggested that high moisture content (9% moisture) in seeds were responsible for decrease of germination and increase of seed-borne infection. The high moisture accelerates the respiration rate of seeds and microorganism and may produce heat thus the quality of seeds deteriorate rapidly. Moreover high moisture initiates incomplete physiological process of seed germination resulting loss of viability of seeds (Harrington, 1973). Ellis and Roberts (1981) suggested that commercial onion seed may be dried to about 6.3% moisture content during store. Athley (1990) observed that onion seed stored with 5% moisture content maintained quality for long term preservation. The results of the present experiment agreed well with the findings of Ellis and Roberts (1981) and Athley (1990).

The results of the experiment revealed that storage conditions have great impact on the quality of seeds in storage. Refrigerator and dehumidified condition maintained better seed quality than ambient condition. All types of containers under controlled condition gave better results and among the containers aluminum foil bag performed best followed by polythene bag and plastic container in maintaining seed quality. But, all packing materials under ambient condition performed inferior and gave lower germination percentage and higher fungal infection. This is due to temperature is lower in controlled condition resulting slow rate of deterioration of seeds under controlled condition and it was high under ambient condition. Malaker *et al*. (2008), Monera *et al*. (1994) and Nakagawa *et al*. (1991) observed similar results in wheat, pea, and okra seed, respectively.

V. Conclusion

Higher germination and lower prevalence of seed-borne was recorded in seeds stored in aluminum foil bag, polythene bag, and plastic container in refrigerator or dehumidified condition. Initial moisture content of seed 5 to 7% also influenced positively on seed germination and prevalence of fungi. Thus, it is suggested that onion seeds may be stored in sealed container and cool condition. The initial moisture content of seed should also be minimum (5 to 7%) for maintaining good quality and health of onion seeds.

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Table 1: Interaction effect of storage containers and seed moisture level on germination and prevalence of seed-borne fungi of onion seed at different period of storage

Treatment combination		Germination (%)			Seed-borne fungi (%)		
Container	Moisture (%)	0 DAS	70 DAS	140 DAS	0 DAS	70 DAS	140 DAS
Aluminum foil bag	5	90	81	77	5.75	5.25	6.00
	7	90	84	82	5.75	5.42	5.50
	9	90	75	63	5.75	6.75	7.67
Polythene bag	5	90	84	81	5.75	5.50	5.92
	7	90	83	81	5.75	5.67	5.58
	9	90	75	56	5.75	7.33	7.83
Metal container	5	90	81	70	5.75	6.25	7.00
	7	90	81	70	5.75	6.50	7.33
	9	90	77	59	5.75	6.58	7.42
Plastic container	5	90	82	80	5.75	6.33	6.67
	7	90	82	78	5.75	6.25	5.92
	9	90	75	57	5.75	7.58	7.67
Earthen pot	5	90	79	61	5.75	7.58	9.25
	7	90	78	62	5.75	8.33	9.33
	9	90	77	50	5.75	8.58	10.42
CV (%)			4.04	5.08		15.14	14.22
LSD (0.05)			2.594	2.800		0.814	0.837

DAS= Days after storage

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Table 2: Interaction effect of storage containers and storage condition on germination and prevalence of seed-borne fungi of onion seed at different period of storage

Treatment combination		Germination (%)			Seed-borne fungi (%)		
Container	Storage condition	0 DAS	70 DAS	140 DAS	0 DAS	70 DAS	140 DAS
Aluminum foil bag	Ambient	90	76	69	5.75	7.00	8.83
	Refrigerator	90	83	77	5.75	5.25	5.08
	Dehumidifier	90	81	75	5.75	5.17	5.25
Polythene bag	Ambient	90	78	69	5.75	6.67	7.25
	Refrigerator	90	82	72	5.75	6.17	6.00
	Dehumidifier	90	82	72	5.75	5.60	6.08
Metal container	Ambient	90	77	64	5.75	8.33	10.67
	Refrigerator	90	82	68	5.75	5.67	5.58
	Dehumidifier	90	80	66	5.75	5.33	5.50
Plastic container	Ambient	90	78	67	5.75	8.33	9.67
	Refrigerator	90	80	73	5.75	6.00	5.33
	Dehumidifier	90	81	74	5.75	5.83	5.25
Earthen pot	Ambient	90	79	57	5.75	9.33	12.58
	Refrigerator	90	78	60	5.75	7.75	7.92
	Dehumidifier	90	78	61	5.75	7.42	8.50
CV (%)			4.04	5.08		15.14	14.22
LSD (0.05)			2.594	2.80		0.814	0.837

DAS = Days after storage

Table 3: Interaction effect of seed moisture level and storage condition on germination and prevalence of seed-borne fungi of onion seed at different period of storage

Treatment combination		Germination (%)			Seed-borne fungi (%)		
Moisture (%)	Storage condition	0 DAS	70 DAS	140 DAS	0 DAS	70 DAS	140 DAS
5	Ambient	90	80	72	5.75	7.45	9.50
	Refrigerator	90	83	75	5.75	5.70	5.75
	Dehumidifier	90	81	74	5.75	5.40	5.65
7	Ambient	90	82	73	5.75	7.70	9.10
	Refrigerator	90	83	76	5.75	5.95	5.55
	Dehumidifier	90	81	74	5.75	5.80	6.20
9	Ambient	90	71	50	5.75	8.65	10.80
	Refrigerator	90	77	61	5.75	6.85	6.65
	Dehumidifier	90	79	60	5.75	6.45	6.50
CV %			4.04	5.08		15.14	14.22
LSD (0.05)			2.009	2.169		0.604	0.648

DAS= Days after storage

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Global Journal of Science Frontier Research: D
Agriculture and Veterinary
Volume 18 Issue 3 Version 1.0 Year 2018
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Response of Leek (Allium ampeloprasum var. porrum L.) Varieties to Plant Spacing at Boloso Bombe, Southern Ethiopia

By Birhanu Lencha & Dawit Dalga
Wolaita Sodo University

Abstract- Leek (Allium ampeloprasum var. porrum L.) is one of the Allium vegetable crop growing in Ethiopia. However; the production and productivity of leek is not as such expected because of lack of appropriate planting space and ideal variety for the specific areas. Hence, a field experiment was carried out to determine the effect of plant spacing on three leek varieties at Areka in Southern Ethiopia. Factorial combinations of three leek varieties (Carentan Giant, Lancelot and Dawn Giant) with three inter-row spacing (20, 30 and 40 cm) and two intra-row spacing (10 and 15 cm) were laid out in a randomized complete block design with three replications. All Phenological, growth, yield components and yield parameters were recorded meticulously for necessary statistical data analysis. The revealed data indicated that days to 90% physiological maturity, leaf length, leaf width, leave number per plant, plant height, dry matter weight, biological yield and total pseudo stem yield were significantly affected by the main effect of variety, inter- and intra-row spacing.

Keywords: *boloso bombe; intra spacing; inter spacing and pseudo stem yield.*

GJSFR-D Classification: *FOR Code: 079999*



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Response of Leek (*Allium ampeloprasum* var. *porrum* L.) Varieties to Plant Spacing at Boloso Bombe, Southern Ethiopia

Birhanu Lencha [α] & Dawit Dalga [σ]

Abstract- Leek (Allium ampeloprasum var. porrum L.) is one of the Allium vegetable crop growing in Ethiopia. However; the production and productivity of leek is not as such expected because of lack of appropriate planting space and ideal variety for the specific areas. Hence, a field experiment was carried out to determine the effect of plant spacing on three leek varieties at Areka in Southern Ethiopia. Factorial combinations of three leek varieties (Carentan Giant, Lancelot and Dawn Giant) with three inter-row spacing (20, 30 and 40 cm) and two intra-row spacing (10 and 15 cm) were laid out in a randomized complete block design with three replications. All Phenological, growth, yield components and yield parameters were recorded meticulously for necessary statistical data analysis. The revealed data indicated that days to 90% physiological maturity, leaf length, leaf width, leave number per plant, plant height, dry matter weight, biological yield and total pseudo stem yield were significantly affected by the main effect of variety, inter- and intra-row spacing. As the inter- and intra-row spacing increases the days to 90 % physiological maturity and leaf number per plant increases whereas biological and pseudo stem yield decreases. Variety 'Dawn (454.82 kg ha^{-1}) and 'Lancelot' (427.93 kg ha^{-1}) had the highest biological yield whereas variety Carentan Giant had the lowest biological yield (147.90 kg ha^{-1}). Likewise, variety 'Dawn Giant' at 15 cm intra-row spacing gave the highest number of leaf width while variety Carentan Giant at 10 cm intra-row spacing gave the lowest. From this, it could be concluded that leek varieties (Carentan Giant, Lancelot' and 'Dawn Giant') could be planted at optimum spacing of 20 cm x 10 cm at Boloso bombe area to attain maximum yield though it is done in one season and location.

Keywords: boloso bombe; intra spacing; inter spacing and pseudo stem yield.

I. Introduction

Leek (*Allium ampeloprasum* var. *porrum* L.) belongs to the genus *Allium* of the family *Alliaceae* (Hanelt, 1990). It is closely related to the onions. It is a biennial plant and its reproductive system is predominantly cross-fertilization although self-fertilization is possible (Meer and Hanely, 1990). It is a slow growing monocotyledonous species of the genus; it is characterized by broad, flat, tightly wrapped, dark green leaves, a long, thick white stalk, and a slightly (to some extent) bulbous end. It is very tolerant to cold weather, although the optimum temperature for vegetative growth is around 20°C. The leaves and long white blanched stem are eaten cooked or can be added to salads (Theunissen and Schelling, 1998).

It is one of the most important pseudo-stems crops cultivated commercially in nearly most parts of the world (Simon, 1992). It contributes significantly to nutritional value of the human diet and is primarily consumed for its unique flavour or for its ability to enhance the flavor of other foods. Its distinctive pungency is due to the presence of a volatile oil. The mature bulb contains some starch, appreciable quantities of sugars, some protein, and vitamins A, B, and C (Decoteau, 2000). It is also used as preservative and medicine (Vohra *et al.,* 1994).

In Ethiopia, the *Alliums* group are among the most important bulb crops produced by small farmers and commercial growers both for local uses as well as for export Metasebia (1998) Leeks are spread throughout the country, being cultivated under both irrigated as well as rain fed conditions in different agro-climatic regions. The best growing altitude for onion, shallot and leeks under Ethiopian condition is between 700 and 1800 m a.s.l (Lemma and Herath, 1992; Aklilu, 1997). Statistics on the production of Vegetables in Ethiopia showed that about 349,079ha of land are cultivated and 2,789,202 hectares produced (CSA, 2017). However, currently, there is no information about the area and the status of leek production in Ethiopia (FAOSTAT, 2010; (CSA, 2017).

The commercial product of leek is its pseudo-stem and leek's pseudo-stem yield varies depending on cultivar, sowing date and planting density (Mondal, 1985). The author further indicated that bulb yield increases with plant density and that this positively correlates with the percentage light interception by the crop leaf canopy. In addition, Brewster (1994) reported that leek bulb yield increased asymptotically as plant density increases and that mean bulb size correspondingly declined.

Considering the importance of leek as one of the potential vegetable crops for both domestic consumption and export in Ethiopia, but there are many constraints that reduce leek production and productivity among which lack of improved varieties and non optimum plant spacing are the majors. It is very important to increase its productivity along with

Author: College of Agriculture, Wolaita Sodo University, Wolaita Sodo, Ethiopia. e-mail: dawitdalga9@gmail.com

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appropriate management practices. However; there is no location and variety specific recommendation on the plant spacing of leek cultivars in study area. In view of the above facts, this study was initiated with the objective to determine the effect of plant spacing on growth, yield components and yield of leek varieties.

II. Materials and Methods

a) Description of the Study Area

A field Experiment was conducted during 2016 off cropping season at Farawoch fruit vegetable nursery site of Boloso Bombe in Southern Ethiopia. A geographical coordinates of the study site is located at 7°08′15.1"N latitude and 37° 41''.330' E longitude having an altitude of 1730 meter above sea level. The experimental site is characterized with bimodal rainfall distribution pattern which extends from March to September and receiving mean annual rainfall of 1459.1 mm. The mean annual minimum and maximum temperature of the site was 15 and 26°C, respectively. Soil types of the study area is sandy loam (BBWARDO, 2011).

b) Description of Experimental Materials

The Leek varieties used in the study were: Carentan Giant (CG), 'Lancelot' and 'Dawn Giant' which were obtained from Haramaya University.

Table 1: The description of the varieties of Leek used in the study

Variety	Year of release	Area of adaptation		Maturity days	Yield (t ha^{-1})	
		Altitude(m)	Rainfall(mm)		On research field	On-farm Field
Carentan Giant	Un	1800-2400	700-1200	100-138	Unknow	2.1
'Lancelot'	Un	1800-2600	700-1200	120-150	2.0-3.5	1.5
'Dawn Giant'	2004	1800-2600	700-1200	70-120	150 stalks	---

Source: HoAA (2004).

c) Treatments and Experimental Design

The experiment was conducted using three factorial combinations of three Carentan, 'Dawn Giant' and 'Lancelot' varieties with three inter-row spacing (40, 30 and 20 cm) and two intra-row spacing (15 and 10 cm). It was conducted by using Randomized Complete Block Design with factorial arrangement and replicated three times. Plots having 40, 30 and 20 cm inter-row spacing accommodated 6, 8 and 12 rows, respectively from which the middle 4, 6 and 10 rows were harvested. Gross plot size was 2.4 m x 3 m (7.2 m^2). Spacing of 0.6 m and 1 m were allocated between plots and blocks, respectively.

d) Soil Sampling and Analysis

A composite initial soil sample of 0-30 cm soil depth was taken from the experimental site before planting and analyzed for physico-chemical properties. Then, taken sample was air-dried, ground using a pestle and mortar, and allowed to pass through a 2 mm sieve. The soil sample was taken to Soil Analytical Testing Service Laboratory and analysed at Wolaita sodo in Ethiopia. Analysis of organic matter content of the soil in a laboratory was determined by using Walkely and Black procedure (Walkely and Black, 1934) and total nitrogen by Micro Kjeldhal method (Jackson, 1958). Soil reaction (pH) was analysed using a pH meter with 1:2.5 soil to solution ratio via a glass electrode attached, and Cation exchange capacity was measured after saturating the soil with 1N ammonium acetate (NH_4OAc) and displacing it with 1N NaOAC (Chapman, 1965). Available phosphorous was determined by the Olsen method (Olsen *et al*., 1954) and exchangeable potassium by flame photometer. Soil texture analysis was performed by Bouyoucous hydrometer method (Bouyoucous, 1951).

e) Data Collection

The data on crop growth, yield components and yield were recorded from sampled plants randomly from middle rows of each plot.

Plant height (cm): It was measured in centimetres from the ground level to the top of the plant at 30 days after transplanting (DAT) and at maturity from15 randomly selected plants.

Days to maturity (No): The total number of days from emergence until 90% of the plants attained physiological maturity. This refers to the time required by the plant to reach the stage when 90% of the pseudo-stems (leaves) were having started to senesce.

Number of leaves per plant (No): This was counted as the total number of leaves and was recorded at 30 DAT and at maturity from 10 randomly selected plants per plot.

Leaf length (cm): The average length of long leaf of the plants was measured at 30 DAT and at maturity from 10 randomly selected plants.

Leaf width (cm): The diameter of the longest leaf at the time of maturity was measured from the sample plants and expressed in centimetre.

Pseudo-stem height (cm): The average pseudo-stem height was grouped into blanched edible parts of 10 randomly taken mature pseudo-stem after harvest.

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Pseudo-stem yield (marketable, unmarketable and total yield) (kg ha^{-1}): Marketable and unmarketable pseudo-stem number and weight per plot were recorded and by adding up both total pseudo-stem yield per plot determined. The data were taken from plants in the five middle rows at harvest. Unmarketable pseudo-stem was identified by experienced Leek trader through subjective evaluation and recorded as the weight and number of diseased, insect attacked and abnormal bulbs. The data were converted to estimate marketable, unmarketable yield per hectare (kg ha^{-1}).

Biological fresh matter yield (kg ha^{-1}): This was recorded as the total fresh weight of physiologically mature plant parts, including pseudo-stems, leaves and roots per plot, taking plants in the central rows of each plot and converted in to hectare (kg ha^{-1}).

f) Statistical Data Analysis

Collected data were subjected to analysis of variance (ANOVA) according to the Generalized Linear Model (GLM) of SAS version 9.1 and interpretations were made following the procedure of Gomez and Gomez (1984). Mean separations were done using Least Significance Difference (LSD) test at 5 % level of significance.

III. Results and Discussion

a) Physico- chemical properties of experimental soils

The laboratory analysis of soil samples from the top soil (0-30 cm) taken before planting was done for the selected physical and chemical properties of soil and has a rate of clay textural class.

Table 2: Selected physical and chemical properties of the experimental site soil

No	Soil characteristics	Value	Rate	Reference
1	pH (by 1: 2.5 soil water ratio)	7.19	Neutral	Bruce and Rayment,1992
2	Total nitrogen	0.08%	Low	Bruce and Rayment,1992
3	CEC	5.34 cmol (+)/kg	high	Charman and Roper,2007
4	Available phosphorus	22.04mg/kg	High	Moody and Bolland,1999
5	Organic matter	1.93 %	High	Charman and Roper,2007
6	Exchangeable K	1.55 cmol (+)/kg	High	Brady,1984
7	Soil texture:			
	% clay	74		
	% sand	4		
	% silt	22		
	Soil textural class		Clay	Mcdonald *et al.,*1994

b) Days to Maturity

Highly significant differences (P<0.01)were recorded on the number of days to 90% physiological maturity due to main effects of variety, inter and intra-row spacing. The number of days taken to reach 90 % physiological maturity for varieties Carentan Giant, 'Dawn Giant' and Lancelot' leek were 111.50, 111.67 and 109.50 days, respectively (Table 3). Carentan Giant and 'Dawn Giant' varieties were matured late than that of Lancelot' variety. However, there was no significant difference between varieties; Carentan Giant and 'Dawn Giant' also differences among cultivars in time to physiological maturity of leek. This might be due to genetic variation of the leek varieties and again intra specific competition of the crop. In line with this, Ali et al.(1999) reported that as intra-row spacing decreased, days to maturity was found to be increased on shallot crop.

The main effects of inter-row spacing showed a highly significant effect (P < 0.01) on the number of days to 90 % physiological maturity, the number of days taken to 90 % physiological maturity increases as the inter-row spacing increases i.e. plots having 20 cm inter-row spacing matured earlier than 30 and 40 cm inter-row spacing. When inter-row spacing increases from 20 to 30 and 20 to 40 cm inter-row spacing, the maturity period increases by 1.55, 1.79%. Moreover; Plots having 10 cm intra-row spacing matured 1.78 days earlier than plots having 15 cm intra-row spacing (Table 3). In this study, it was generally observed that wider intra-row spacing delayed 90% physiological maturity. Similarly, Jilani (2004) reported that there was difference in physiological maturity of onion cultivars and also reported the intra-row spacing increased from 10 to 15 cm, the days to 90 % physiological maturity increases by 1.60%.

c) Plant height

Analysis of variance exhibited significant differences (P < 0.05) due to the main effects of variety on plant height at 90 % physiological maturity. The highest height of plant was recorded for variety Carentan Giant (41.24 cm) followed by 'Dawn Giant' (39.17cm) while the lowest height was recorded on variety Lancelot' (37.82cm). Variety Carentan Giant was significantly different from variety Lancelot'on plant height while variety 'Dawn Giant' was found with the same level of significance with both Carentan Giant and Lancelot' (Table 3). The variation in height might be due to genetic characteristics of the varieties for this trait.

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Plant height was not affected significantly by the main effects of inter- and intra-row spacing. The non-significant effect of crop density on mean plant height observed in this study might be attributed to the fact that crop density has often, but not always been associated with increased plant height. Increase in plant population markedly would increase plant height of leek. All interaction effect also did not influence significantly the height of leek varieties. This result was in agreement with Mondal et al. (1986) who reported that genotypes of onion were significantly differed in plant height. And also Zamil et al. (2010) who reported that the widest spacing enhances growth and height of the plant which was significantly different from narrow spacing.

Table 3: Mean values of Leaf length, days to 90 % physiological maturity (DM), Leaf width and Plant height (PH) as affected by the main effects of variety, inter and intra row spacing in southern Ethiopia

Treatments	Leaf width (cm)	Leaf length (cm)	DM (days)	PH (cm)
Variety				
Carentan Giant	10.94a	40.78c	111.50a	49.24a
'Dawn Giant'	8.04c	39.17c	111.67a	48.50a
Lancelot'	9.66b	46.33b	109.50b	37.82b
LSD (5%)	0.62	0.89	1.32	2.23
Inter-row spacing(cm)				
20	10.11b	42.17b	109.50b	39.47
30	10.28a	42.94ab	111.22a	38.97
40	9.06c	43.50a	111.95a	39.80
LSD (5%)	0.17	0.89	1.32	Ns
Intra-row spacing (cm)				
10	69.57	42.07b	110.00b	39.61
15	74.90	43.67a	111.78a	39.21
LSD (5%)	Ns	0.73	1.08	Ns
C.V (%)	9.95	3.08	1.76	8.34

Means with in columns followed by the same letters are non significantly affected at 5 % probability level. LSD = Least significant Different and CV (%) =coefficient of variation

d) Yield Components

i. *Leaf Length*

The main effects of variety, inter and intra row spacing on leaf length of Leek plants showed significance difference (Table 3). Varieties Carentan Giant (40.78cm) and 'Dawn Giant' (41.50cm) as compared to 'Lancelot (46.33cm). Significant difference was observed between variety 'Lancelot and the other two varieties. This might be attributed to the facts that leave length in leek are considering variety characteristics, which is genetically controlled. The highest leaf length was recorded from Carentan Giant (43.50cm) in 40 cm inter row spacing followed by 'Lancelot' (42.9cm) in 30cm inter row spacing while the lowest leaf length was 'Dawn 42.17 cm in 20 cm inter-row spacing (Table 3). The 20 and 30 cm inter row spacing were found to be non significant to each other but they were significantly different from 40 cm inter row spacing. When the inter row spacing increased from 20 to 40 cm, leaf length increased.

Similarly the intra row spacing increased from 10 to 15 cm, the leaf length increased by 3.66 % (Table 3). Plots having wider inter row spacing and intra row spacing length significantly larger than that of narrower inter and intra row spacing. In contrast to this finding, Hussain et al. (1998) and Marschner (2007) reported that the non-significant effect of plant population on plant length onion.

ii. *Number of Leave per plant*

The effects of variety, inter and intra row spacing ($p < 0.05$) and the interaction effects of variety, inter row spacing and intra row spacing was a significant influence on the number of leave plant^{-1} (Table 4). Variety 'Dawn Giant' at 40 cm inter row spacing gave the highest number of leaves (4.30) while variety Carentan Giant at 20 cm inter row spacing gave the lowest number of primary branches (2.03). The number of leaves of two varieties ('Dawn Giant' and Lancelot') decreased with decreased inter row spacing whereas; the inter row spacing increases from 20 to 40 cm, the number of leaves of varieties 'Dawn Giant' and Lancelot' increases by 32.09 and 31.76 %, respectively. The decreased inter row spacing resulted in more plants per unit area and hence less number of leaves plant^{-1} due to more competition for nutrients, light, water and air. Significant differences were recorded among varieties at all inter row spacing. Carentan Giant significantly gave lower number of leaves than the other two varieties at all inter row spacing but there was no significant difference between varieties. The significant difference among varieties in all inter row spacing could be due to the differences in growth habit. Similarly, Singh et al. (2005) reported that the increased in number of primary branches with decreased plant density in garlic crop.

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Table 4: Leaves per plant as affected by inter spacing, intra spacing, variety and interaction in Southern Ethiopia

Inter-row spacing(cm)	Variety		
	Carentan Giant	'Dawn Giant'	Lancelot'
20	12.03d	12.92c	12.90c
30	12.35d	13.93ab	13.57b
40	12.47cd	14.30a	14.25a
LSD (5%)	0.54		
C.V (%)	13.25		
Intra-row spacing (cm)			
10	12.27c	13.60ab	13.20b
15	12.30c	13.83a	13.94a
LSD (5%)	0.60		
C.V (%)	13.25		

Means with in columns followed by the same letters are non significantly affected at 5 % probability level. LSD = Least significant Different and CV (%) =coefficient of variation

e) Pseudo-stem diameter plant^{-1}

Analysis of variance showed that significantly different at ($P < 0.01$) for Pseudo-stem diameter plant^{-1}. The highest Pseudo-stem diameter plant^{-1} was recorded for variety 'Dawn Giant' (27.59) followed by variety Lancelot' (24.88) while the lowest number of pods plant^{-1} was recorded for variety Carentan Giant (17.12) (Table 5). The differences in Pseudo-stem diameter plant^{-1} might be due to varietal differences and the productive capacity of Leek crop is ultimately considered by the Pseudo-stem diameter plant^{-1}. Significant variation was existed between 20 and the other inter row spacing but similar significance level were found between 30 and 40 cm inter row spacing. Higher pseudo-stem diameter plant^{-1} in 40 cm apart inter rows might be due to low competition of plants in the field which facilitated more aeration, greater light interception and more photosynthetic activity per individual plant. Similarly, Islam (1988) also reported that higher yields of pseudo-stem diameter can be achieved as row spacing is reduced where inter and intra row spacing's were none-significant. The main effects of varieties, inter and intra row spacing significantly affected. However, the highest pseudo stem yield of 19.07cm green part had occurred for variety Lancelot followed by variety Dawn (16.41cm) while the lowest seed yield was obtained for variety Carentan (15.93cm) and have a response in pseudo stem length of the green part of the Leek (Table 5). In contrast to this finding, Baker (1998) reported that in the narrow intra row spacing of leek crop were decrease in pseudo-stem length could be due to the presence of high competition for growth factors at wider spacing.

Table 5: The main effects of varieties, inter and intra row spacing on pseudo-stem diameter, biological fresh yield weight (BFMY) and dry-matter content of Leek in Southern Ethiopia

Treatment	Pseudo-stem diameter	Pseudo-stem length	Fresh Matter (g plant^{-1})	Dry matter (%)
Carentan	38.18	5.92b	72.70^{d}c	10.96
Dawn	29.62	6.96b	82.9^{ab}	11.27
Lancelot	26.84	9.96a	93.80^{a}	11.15
LSD(0.05)	11.34	14.04	26.60	NS
Intra row spacing and intra-spacing(cm)				
5x20	28.38	5.78	88.10	11.91
10x30	27.59	5.72	78.60	10.83
15x40	25.58	6.38	70.40	11.21
LSD(0.05)	02.80	NS	11.01	NS
CV (%)	13.3	16.2	35.4	17.3

Means followed by the same letter within a column are not significant different at 5% level of significance; NS= not significant, LSD = Least Significant Difference and CV = Coefficient of variance

f) Fresh matter Yield

Analysis of variance showed that the biological fresh matter yield of Leek significantly ($P<0.05$) affected due to the main effects variety, intra and inter row spacing. The highest biological Fresh matter yield was recorded in Lancelot variety with 20 cm inter row

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spacing while the lowest yield (72.70) was recorded in 40 cm inter-rows (Table 5). This might be due to genetic potential of the crop and plant density variation. Similarly, Getachew et al. (2013) reported that different varieties with vary inter row spacing gave different fresh matter weight in shallot crop.

g) Marketable and Unmarketable pseudo stem

The interaction effects of varieties and inter-intra row spacing did not show significant effect on the number of unmarketable pseudo-stems of leek. On the other hand, the number of marketable pseudo-stems was highly significantly affected ($P<0.01$) by the intra row spacing. The highest number of stems plant^{-1} was recorded for variety 'Dawn Giant' (27.59) followed by variety 'Lancelot' (24.88) while the lowest number of stems plant^{-1} was recorded for variety Carentan Giant (17.12) (Table 6). As the inter-row spacing increases from 20 to 40 cm, the number of pseudo stem (shaft) per plant increases. Significant variation was existed between 20 cm and the other inter-row spacing but similar significance level were found between 30 and 40 cm inter-row spacing. Average number of pseudo stem plant^{-1} was increased by 10.72 and 12.51% as the inter-row spacing was increased from 20 to 30 cm and 20 to 40 cm, respectively (Table 6). Higher number of pseudo stem plant^{-1} in 40 cm apart inter-rows might be due to low competition of plants in the field which facilitated more aeration, greater light interception and more photosynthetic activity per individual plant. Number of pseudo stem (shaft) per plant is a key factor for determining the yield performance in *allium* plants. The productive capacity of leek plant is ultimately considered by the number of pods plant^{-1}.

Higher average number of pseudo stem plant^{-1} (24.06 stems) was noted in 15 cm intra-row spacing and the lower number of pods plant^{-1} (22.34 stems) was recorded in plots with 10 cm intra-row spacing (Table 6). The wider intra-row spacing produced the higher number of stems plant^{-1} because of sufficient space and plants utilized more water, light, air and nutrients as a result, more photosynthetic activity, which eventually resulted in higher number of pods plant^{-1}. The reduction in number of stems plant^{-1} (7.15 %) in narrower intra-row spacing might be due to higher number of plant per unit area where competition for nutrients, light, space and moisture was very tense as compared with the wider intra-row spacing. Similarly, Baker (1998) reported that in the narrow intra row spacing of leek crop were decrease in marketable stem at wider spacing.

h) Total Biological Yield

Variety 'Dawn (454.82 kg ha^{-1}) and 'Lancelot' (427.93 kg ha^{-1}) had the highest biological yield whereas variety Carentan Giant had the lowest biological yield (147.90 kg ha^{-1}) (Table 6). However, all varieties showed statistically non-significant differences. The productivity of a crop is largely determined by the biological yield. Production of large amount of biomass is among one of the attributes of seed yield. The decrease in biological yield due to low branching habit and low number of pods per plant of variety Carentan Giant might be compensated by the increased in other parameters such as plant height, seed weight and stem thickness.

As the inter-row spacing increases, the biological yield also increases and hence, the highest biological yield 863.23 kg ha^{-1}) was recorded in 20 cm inter-row spacing followed by 30 cm with a yield of 167.55 kg ha^{-1} while the lowest biological yield (899.88 kg ha^{-1}) was obtained from 40 cm inter-row spacing (Table 6). Inter-row spacing having 20 cm was significantly affected and 30 and 40 cm inter-row spacing but non-significance effect was recorded between 30 and 40 inter-row spacing. The biological yield was increased by 24.94 and 18.01% when inter-row spacing was changed from 40 to 20 cm and 30 to 20 cm, respectively. This finding was in agreement with Gan et al. (2003) reported that increasing yield of onion at high density. Bahr (2007) also reported that high plant density (30 plants m^{-2}) gave higher seed yield as compared to low plant density (26 plants m^{-2}) in Leek crop.

i) Pseudo-stem yield

The main effects of variety did not influence the pseudo-stem yield of Leek varieties. However, the highest stem yield of 1026.68 kg ha^{-1} had occurred for variety 'Lancelot' followed by variety 'Dawn Giant' (911.50 kg ha^{-1}) while the lowest stem yield was obtained for variety Carentan Giant (CG),(821.77 kg ha^{-1}) (Table 6). The decreased in pseudo stem yield due to short shaft habit and stunt of pseudo stem per plant for variety Carentan Giant variety might be compensated by other parameters such as stem weight. Pseudo-stem yield and its transformation into economic yield is the ultimate outcome of various physiological and morphological events occurring in the plant system. Pseudo-stem yield varies with in varieties is as a result of interplay of its genetic makeup. The interaction effects of all treatment combinations for this parameter were also non-significant. In line with this result, Brittain (1988[c]) found that narrow inter-row spacing (30 cm) gave the highest seed yield as compared to wider spacing of 45 and 60 cm on Leek varieties.

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Table 6: Main effects of varieties, intra and inter row spacing on the number of Marketable pseudo stem, number of unmarketable pseudo stem (NUMARPS), biological yield (TBY and Pseudo-stem yield (PSY) at Boloso Bombe, Southern Ethiopia

Treatments	NM	NUMPS	TBY (kg/ha)	TY (kg/ha)
Variety				
Carentan Giant	17.12c	1.06	137.90	821.77
'Dawn Giant'	27.59a	1.07	454.82	911.50
Lancelot	24.88b	1.09	427.93	1026.68
LSD (5%)	1.58	Ns	Ns	Ns
Inter-row spacing (cm)				
20	21.33b	1.06	863.23a	2340.33a
30	23.89a	1.08	167.55b	1800.45b
40	24.38a	1.07	899.88b	1619.16b
LSD (5%)	1.58	Ns	98.51	250.89
Intra-row spacing (cm)				
10	22.34b	1.06	3599.85a	2081.65a
15	24.06a	1.08	3020.58b	1758.32b
LSD (5%)	1.29	Ns	325.38	204.85
C.V (%)	10.06	9.20	17.77	19.29

Means followed by the same letter within a column are not significant different at 5% level of significance; NS= not significant, LSD = Least Significant Difference and CV = Coefficient of variance

The main effects of inter and intra row spacing caused a highly significant effect ($p < 0.01$) on the total yield of Leek varieties. The highest average total yield (2340.33 kg ha^{-1}) was recorded in 20cm inter row spacing followed by 30cm inter rows with average total yield value of 1800.45 kg ha^{-1} while the lowest yield (1619.16 kg ha^{-1}) was recorded in 40 cm inter rows (Table 6). But there was no statistically significant difference between 30 and 40 cm inter row spacing. The total yield was decreased by 23.07 and 30.81 % when inter row spacing was increased from 20 to 30 cm and 20 to 40 cm inter row spacing, respectively (Table 6). The higher pseudo stem yield (2081.65 kg ha^{-1}) was recorded in 10 cm intra row spacing and lower yield of 1758.32 kg ha^{-1} was recorded in plots with 15 cm intra row spacing. When intra row spacing was increased from 10 to 15 cm, the yield was decreased by 15.53 %.

IV. Conclusion

Generally, this study revealed that Leek varieties total yield increased in individual basis due to the favor of spacing did not compensate the increase in total pseudo stem yield due to the favor of population per unit area basis at Farawoch site of Boloso Bombe Woreda, in Wolaita Zone, Southern Ethiopia. The analyzed data indicated that days to 90% physiological maturity, leaf length, leaf width, leave number per plant, plant height, dry matter weight, biological yield and total pseudo stem yield were significantly affected by the main effect of variety, inter- and intra-row spacing. As the inter and intra row spacing increases the days to 90% physiological maturity and leaf number per plant increases whereas biological and pseudo stem yield decreases. Likewise, variety 'Dawn Giant' at 15 cm intra row spacing gave the highest number of leaf width while variety Carentan Giant at 10 cm intra row spacing gave the lowest. Variety 'Dawn (454.82 kg ha^{-1}) and 'Lancelot' (427.93 kg ha^{-1}) had the highest biological yield whereas variety Carentan Giant had the lowest biological yield (147.90 kg ha^{-1}). From this finding, it could be concluded that Leek varieties (Carentan Giant, Lancelot' and 'Dawn Giant') could be planted at optimum spacing of 20 cm x 10 cm at Boloso Bombe area to attain maximum yield. However, this study conducted in one season and one location, further study across location and season is suggestible for remarkable recommendation.

Acknowledgements

The authors thanks the Wolaita Sodo University for providing the budget for this research and Boloso Bombe Agricultural Office for providing research materials and necessary facilities.

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Global Journal of Science Frontier Research: D
Agriculture and Veterinary
Volume 18 Issue 3 Version 1.0 Year 2018
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Productivity Increment of Lentil Adopting on-Farm Seed Priming in Rainfed Hill Environment of Nepal

By Keshab Babu Koirala
National Maize Research Program, Nepal

Abstract- Lentil varieties namely Shishir, Shimal, Shikhar and Khajura Masuro-2 were experimented at three locations of Myagdi, Palpa and Gorkha districts adopting mother-baby trial design with primed and non-primed treatments with an objective of identifying and promoting seed priming technology of lentil in rainfed environment of western hills in Nepal. Combined results of mother trials over sites of three districts revealed that in lentil primed seeds flowered and attained maturity 2-3 and 3-6 days earlier compared to non-primed counterpart. In an average grain yield increament was recorded 13.6% and reached up to 19.4% in Shimal due to priming. Both genotype and location specific effect on observed traits due to priming were recorded. Khajura Masuro-2 (1507 kg ha-1) and Shikhar produced highest grain yield under primed and non-primed (1408 kg/ha) situation, respectively. Combined farmers' feedback from babies showed better germination and good plant stand of soaked seeds over non-soaked. Earlier maturity in Shimal was feedback from 95.8% of the respondents. Better results of primed seeds for grain yield production in Khajura Masuro-2, Shishir, Shikhar and Shimal were claimed by 75.0%, 83.3%, 91.7% and 95.8% of participating farmers, respectively. Huge percentage (91.7 to 95.8 %) of farmers showed their keen tnterest to continue this technology in future, too.

Keywords: *lentil, seed, priming, genotype, yield.*

GJSFR-D Classification: *FOR Code: 309999*



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I. Introduction

Among the pulses, lentil ranks third in the western hills after black gram and soyabean in terms of area (1614 ha) and production (1778 Mt.) with productivity of 1102 kg ha^{-1}. It occupies 62.92% (205939 ha) of the total (327321 ha) pulses' area with 69.58% (253041 Mt.) grain production in Nepal with average productivity of 1113 kg ha^{-1} (MoAD, 2017). Lentil is the cheapest source of protein, and rich in calcium and iron for human diet particularly for the women, children, elderly population and resource-poor community of the country. In Nepal, its straw is used as animal feed. Similarly, it enhances fertility status of soil and checks soil erosion as cover crop. Along with varietal improvement, there is an urgent need to enhance overall production and productivity of this crop adopting suitable agronomic management practices (Anonymous, 2002a). Darai and his colleagues (2008) stated that according to FAOSTAT (2004), in the world export market Nepali lentil's share is about 2%. In Nepal, lentil is generally grown as a rainfed winter crop relying on residual soil moisture which results moisture stress during sowing and podding (Darai et al., 2008) periods resulting reduced yield.

Various methods of seed priming viz. on-farm seed priming, hydro-priming, halo priming (organic salts like NaCl, $KN0_3$, $CaCl_2$, $CaS0_4$ etc. are used in soaking seeds), osmo-priming (seeds are soaked in solutions of sugar, polyethylene glycol, glycerol, sorbitol, or mannitol) and hormonal priming (kinetin, ascorbate, salicylic acid etc.) are being experimented on lentil (Harris; Binang et al., 2012; Nawaz et al., 2013; Pakbaz et al., 2014; Toklu, 2015 and Singh et al., 2017). Seed priming of lentil, chickpea, rice and wheat with micronutrients (B, Zn and Mo) was also experimented (Johnson et al., 2005). Likewise, lentil seed priming with various micronutrients viz. KI (Potassium iodide), copper iodide (CuI), zinc iodide (ZnI_2) and zinc sulphate ($ZnSo_4$) were used by Aliloo and his colleagues (2014). With an objective of identifying affordable seed priming agent of lentil for resource-poor farmers where price of commercial vitamins, antioxidants or nutrients is very high, aqueous plant extracts (*Aloe vera, Moringa olifera* and sugar beet) were also used to enhance rate of germination and seedling growth under chilling conditions (Imran et al., 2014). Seed priming is a useful technology to enhance germination, earlier germination, seedling vigour, stand establishment, competitiveness against weeds, number of tillers, number of fertile tillers, grain yield and tolerance to drought periods. Similarly, it reduces seedling emergence period, duration to maturity and incidence of diseases, and avoids the need for re-sowing in many field crops (Rashid et al., 2002; Binang et al., 2012; Nawaz et al., 2013; Arjmand et al., 2014; Koirala, 2017 and Sharma et al., 2017). Both in legumes and cereals mean grain yield increment was in between zero and 200%, and average increase was about 30% (Harris, 2004). However, effect on yield or micronutrient content of the progeny seeds was not recorded sowing micronutrient (B, Zn and Mo) primed seeds in rice, wheat, lentil and chickpea (Johnson et al., 2005). The hydro-priming improved the morphology of germinated seeds of *Cucurbita pepo* (Bankaji et al., 2017).

Poor seed germination and crop establishment, and needs of re-sowing in some of the cases resulting lower yield are the major problems in lentil growing areas in Nepal. On-farm lentil seed priming/seed soaking

Author: National Maize Research Program, Rampur, Chitwan, Nepal.
e-mail: koiralakb15@gmail.com

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is a simple technology where seed is soaked in tap water for less than "safe limit" i.e. 12 hours. Then, seeds are surface dried by spreading them in the shade for two hours and sown the same day. Seed priming is a low cost and low risk intervention which increases and stabilizes yields. Thus, this technology will have a large impact on the livelihoods of small scale, marginal, resource-poor and socially disadvantaged groups in community.

II. Materials and Methods

Experiments were conducted during winter season at three locations of Gorkha (Birenchok, Shikhar and Katteldanda), Myagdi (Jyamrukkot, Ratnechaur-1 and Ratnechaur-5) and Palpa (Aryabhanjyang, Khaseuli and Deurali) districts. Four varieties of lentil namely Khajura Masuro-2, Shimal, Shishir and Shikhar were evaluated in farmers' fields with primed (P) and non-primed (NP) treatments. "Mother-Baby" (MB) trial's scheme was implemented for experimentation. In baby trials (BTs), one kilogram (kg) seed of each variety was provided to four farmers at each location and asked to prime half of seed in water for 12 hours, then surface dry and sow using normal practices adjacent to a plot using non-primed seed. This trial was managed and led by farmers themselves. Thus, sixteen farmers were involved in BTs at a location. In addition to that, in a centrally situated area of each location a complete set of trial, called mother trial (MT) consisting of four improved varieties used in BTs was tested. MTs provided opportunity to farmers, extension workers and researchers to evaluate and compare the performance of tested technologies in one spot. Thus, total 17 farmers at a location, 51 in a district and 153 in the project participated in testing and verifying lentil seed priming technology.

Farmers compared the performance of each variety with primed and non-primed treatments in BTs and all four varieties together in MTs from planting to post-harvest management. Individual farmer's opinions were collected through a household level questionnaire (HLQ) using matrix ranking where the primed treatment was compared to non-primed counterpart as better, same or worse. In HLQ, feedback was collected on ease to planting, time to germination, plant stand after germination, growth of the plants, days to flowering, weed problem, disease and insect pests problem, drought tolerance, days to maturity, grain size, grain yield and plan for next year planting.

Plot size of MT was 3m × 2m. Seed rate was 20 kg ha^{-1}. Row to row distance was 25 cm and continuous planting within rows. Fertilizers were applied @20:20:40 $N:P_2O_5:K_20$ kg ha^{-1}. Six central rows were used to record observations. MB trial's scheme using four varieties of lentil with primed and non-primed treatments has been presented in figure 1.

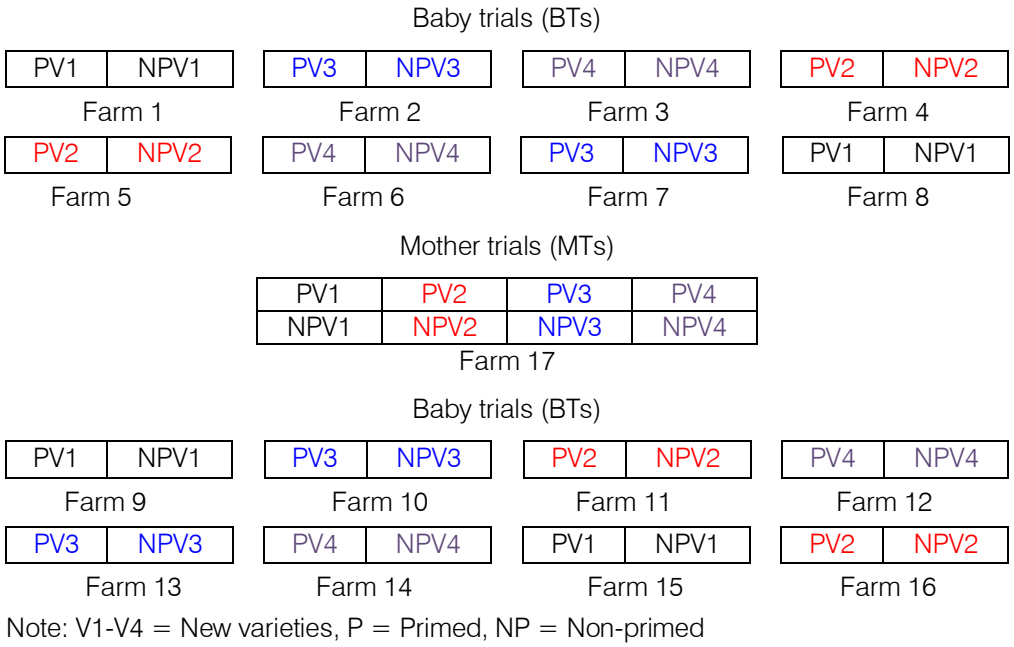

Figure 1: Mother-baby trial's scheme using four varieties of lentil with primed and non-primed treatments

III. Results and Discussion

a) Mother Trial

In Gorkha district, highest grain yield was recorded in Shikhar (1433 kg ha^{-1}) followed by Khajura Masuro-2 (1183 kg ha^{-1}) and Shishir (922 kg ha^{-1}) under primed condition which was better as compared to non-primed counterpart. Due to on-farm seed priming, yield increment at this location ranged from 1.9 (Shikhar) to 13.5% (Shimal). Both under primed and non-primed treatments, in Palpa district, varieties namely Khajura Masuro-2 (1561 and 1200 kg ha^{-1}), Shishir (1528 and

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1194 kg ha^{-1}) and Shikhar (1367 and 1097 kg ha^{-1}) produced higher yield. Primed seed produced 24.6 (Shikhar) to 49.3% (Shimal) higher yield compared to non-primed seeds. In Myagdi, all the tested genotypes except Shikhar produced higher grain yield under primed condition and ranged from -3.3 to 12.8 (Khajura Masuro-2). Results when combined over locations under primed situation, Khajura Masuro-2 (1507 kg ha^{-1}) was the top yielder followed by Shikhar (1489 kg ha^{-1}) and Shishir (1418 kg ha^{-1}), respectively. Highest grain yield was recorded in Khajura Masuro-2 and Shikhar (1408 kg ha^{-1}) under primed and non-primed environment, respectively. Percent yield increment was in between 5.8 (Shikhar) and 19.4% (Shimal) with average increment of 13.6%. Results have been summarized in Table 1. Seed yield increase due to priming in lentil by 31.4 to 36.8% (Neupane, 2002 and Anonymous, 2002b), 24 to 44% (Clements et al., 2003) and 26% (Darai et al., 2008) was recorded. Genotype specific response to yield and other traits due to on-farm seed priming was also recorded (Pakbaz et al., 2014) as we observed in our experiments.

Table 1: Grain yield (kg ha^{-1}) of tested lentil genotypes under primed and non-primed conditions at various locations

Variety	Gorkha			Palpa			Myagdi			Combined over locations		
	Primed	Non-primed	% increment over NP	Primed	Non-primed	% increment over NP	Primed	Non-primed	% increment over NP	Primed	Non-primed	% increment over NP
Shimal	889	783	13.5	1103	739	49.3	1603	1486	7.9	1198	1003	19.4
Khajura Masuro-2	1183	1089	8.6	1561	1200	30.1	1777	1575	12.8	1507	1288	17.0
Shikhar	1433	1406	1.9	1367	1097	24.6	1666	1722	-3.3	1489	1408	5.8
Shishir	922	833	10.7	1528	1194	28.0	1805	1694	6.6	1418	1241	14.3
Mean	1107	1028	7.7	1390	1058	31.4	1713	1619	5.8	1403	1235	13.6
Minimum	889	783	1.9	1103	739	24.6	1603	1486	-3.3	1198	1003	5.8
Maximum	1433	1406	13.5	1561	1200	49.3	1805	1722	12.8	1507	1408	19.4

Days to flowering of the primed genotypes were found earlier as compared to non-primed seeds which ranged from 2-4, 1-4 and 2-6 days in Gorkha, Palpa and Myagdi districts, respectively. Combined results showed that primed seeds of Khajura Masuro-2 and Shikhar flowered 3 days earlier, and Simal and Shishir flowered 4 days earlier as compared to non-primed seeds. Detail results have been presented in Table 2. These primed seeds of various genotypes not only flowered earlier but also matured earlier at all locations. The maturity period of primed seeds as compared to non-primed was recorded earlier by 3-6 and 2-6 days in Gorkha and palpa, respectively. Primed genotypes attained maturity 3-6 days earlier as compared to their non-primed counterparts when combined over locations. Findings have been highlighted in Table 3. Better germination, increased plant stand and increased biomass yield was also recorded (data not presented). Reduced time to germination and enhanced root growth (Clements, 1998 and Clements et al., 2003) were recorded using lentil's primed seeds in laboratory. Better germination, reduced days to 50% emergence, satisfactory seedling emergence, better and uniform plant stand, increased number of pods per plant, larger seed size, increased seed weight per plant, higher seed yield, increased plant height, increased number of primary branches, total biomass yield and harvest index reducing cost of production are the benefits of lentil seed priming for 12 hours (Anonymous, 2002b; Neupane, 2002 and Sharma et al., 2017). In addition to increased seed yield, better grain filling, early maturity (1 week), and less diseases and insectpests problems were identified as additional advantages of primed seeds compared to non-primed counterparts (Darai et al., 2008) reducing risk of crop failure. Similarly, seed priming experiments on improved varieties combined in one exercise provide exposure to new varieties and varietal selection options to growers.

Table 2: Mean days to flowering of lentil varieties under primed and non-primed treatments at various locations

Variety	Gorkha			Palpa			Myagdi			Combined over locations		
	Primed	Non-primed	Days earlier in P	Primed	Non-primed	Days earlier in P	Primed	Non-primed	Days earlier in P	Primed	Non-primed	Days earlier in P
Shimal	70	73	3	75	79	4	73	78	5	73	77	4
Khajura Masuro-2	71	74	3	72	73	1	72	78	6	72	75	3
Shikhar	76	78	2	72	75	3	75	77	2	74	77	3
Shishir	74	78	4	72	75	3	73	79	6	73	77	4
Mean	73	76	3	73	76	3	73	78	5	73	76	3
Minimum	70	73	2	72	73	1	72	77	2	72	75	3
Maximum	76	78	4	75	79	4	75	79	6	74	77	4

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Table 3: Mean days to maturity of lentil varieties under primed and non-primed treatments at various locations

Variety	Gorkha			Palpa			Combined over locations		
	Primed	Non-primed	Days earlier in P	Primed	Non-primed	Days earlier in P	Primed	Non-primed	Days earlier in P
Shimal	117	120	3	123	129	6	120	125	5
Khajura-2	117	121	4	122	126	4	120	123	3
Shikhar	123	129	6	124	126	2	124	128	4
Shishir	120	125	5	122	128	6	121	127	6
Mean	119	124	5	123	127	4	121	126	5
Minimum	117	120	3	122	126	2	120	123	3
Maximum	123	129	6	124	129	6	124	128	6

b) Baby Trials

Feedback from baby trials was recorded from each individual farmer for different pre and post-harvest traits of each variety (Tables 4-7). Farmers' response combined over locations (Table 7) showed that 29.2-45.8% respondents expressed their opinion on the favour of easy planting of primed seed. Stand establishment after germination in soaked seeds was observed better as reported by 29.2-54.2% of the respondents. Genotype Shimal attained earlier maturity as claimed by 95.8% of participating farmers. Majority of the respondents reported non-significant differences in primed and non-primed treatments for weed, disease and insect problems. Sililarly, 91.7%, 95.8%, 83.3% and 75.0% of collaborators reported better performance of primed seed over non-primed in Shikhar, Shimal, Shishir and Khajura Masuro-2, respectively. Likewise, 91.7 to 95.8 % farmers involved in lentil seed priming experiments showed their keen interest to continue lentil seed priming technology in future. Farmers' preferences of lentil genotypes with and without priming treatments in different districts (combined over sites) and combined over locations have been summarised and presented in Tables 4-7. Based on farmers' perceptions in HLQ, focus group discussions (FGD), field day and inter-district observation tour, farmers of Gorkha preferred Shikhar and Shishir whereas in Palpa and Myagdi, Shishir and Khajura Musuro-2 varieties were preferred by farmers. It is recorded that on-farm seed priming technology is not suitable both for too dry and excess moisture conditions. These findings are also supported by Darai and his colleagues (2008). They added, primed seeds emerged 3 days earlier, grew faster, and flowered earlier, showed better drought tolerance and formed grain earlier than non-primed seeds and farmers are able to harvest higher yields 7-10 days earlier than normal sowing.

Table 4: Farmers' preferences on seed priming of different lentil varieties in baby trials, Gorkha

Trait	Shikhar			Simal			Shishir			Khajura Masuro-2		
	1 (%)	2 (%)	3 (%)	1(%)	2 (%)	3 (%)	1 (%)	2 (%)	3(%)	1 (%)	2 (%)	3(%)
Ease to planting	91.7	8.3	0.0	66.7	16.7	16.7	88.9	11.1	0.0	100.0	0.0	0.0
Time to germinate	91.7	8.3	0.0	66.7	0.0	0.0	100.0	0.0	0.0	75.0	25.0	0.0
Plant stand after germination	66.7	33.3	0.0	50.0	50.0	0.0	88.9	11.1	0.0	83.3	16.7	0.0
Growth of the plant	83.3	16.7	0.0	50.0	50.0	0.0	83.3	16.7	0.0	91.7	8.3	0.0
Days to flowering	58.3	41.7	0.0	27.8	72.2	0.0	83.3	16.7	0.0	66.7	33.3	0.0
Weed problem	11.1	88.9	0.0	11.1	88.9	0.0	0.0	100.0	0.0	33.3	66.7	0.0
Insect/pest problem	0.0	100.0	0.0	11.1	88.9	0.0	8.3	91.7	0.0	33.3	66.7	0.0
Drought tolerance	8.3	91.7	0.0	50.0	50.0	0.0	47.2	52.8	0.0	33.3	66.7	0.0
Maturity	75.0	25.0	0.0	16.7	83.3	0.0	91.7	8.3	0.0	33.3	58.3	8.3
Grain size	25.0	75.0	0.0	50.0	50.0	0.0	41.7	58.3	0.0	50.0	50.0	0.0
Grain yield	75.0	25.0	0.0	50.0	50.0	0.0	100.0	0.0	0.0	41.7	50.0	8.3
Plan for next year planting	100.0	-	0.0	47.2	-	52.8	91.7	-	8.3	83.3	-	16.7

Note: 1(%), 2(%), 3(%) – percent respondents reporting better, similar and worse result, respectively of primed seed over non- primed counterpart for each trait

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Table 5: Farmers' preferences on seed priming of different lentil varieties in baby trials, Palpa

Trait	Shikhar			Simal			Shishir			Khajura Masuro-2		
	1 (%)	2 (%)	3 (%)	1 (%)	2 (%)	3 (%)	1 (%)	2 (%)	3 (%)	1 (%)	2 (%)	3 (%)
Ease to planting	41.7	58.3	0.0	50.0	50.0	0.0	41.7	58.3	0.0	50.0	50.0	0.0
Time to germinate	100.0	0.0	0.0	100.0	0.0	0.0	100.0	0.0	0.0	100.0	0.0	0.0
Plant stand after germination	41.7	58.3	0.0	75.0	25.0	0.0	58.3	41.7	0.0	41.7	58.3	0.0
Growth of the plant	91.7	8.3	0.0	91.7	8.3	0.0	83.3	16.7	0.0	66.7	33.3	0.0
Days to flowering	91.7	8.3	0.0	100.0	0.0	0.0	91.7	8.3	0.0	75.0	25.0	0.0
Weed problem	0.0	100.0	0.0	0.0	100.0	0.0	16.7	83.3	0.0	0.0	100.0	0.0
Insect/pest problem	0.0	100.0	0.0	0.0	100.0	0.0	0.0	91.7	8.3	0.0	100.0	0.0
Drought tolerance	58.3	41.7	0.0	75.0	25.0	0.0	75.0	16.7	8.3	41.7	58.3	0.0
Maturity	91.7	8.3	0.0	91.7	8.3	0.0	83.3	16.7	0.0	75.0	25.0	0.0
Grain size	91.7	8.3	0.0	83.3	16.7	0.0	83.3	16.7	0.0	66.7	33.3	0.0
Grain yield	91.7	8.3	0.0	91.7	8.3	0.0	83.3	16.7	0.0	66.7	33.3	0.0
Plan for next year planting	91.7	-	8.3	83.3	-	16.7	91.7	-	8.3	83.3	-	16.7

Note: 1(%), 2(%), 3(%)–percent respondents reporting better, similar and worse result, respectively of primed seed over non-primed counterpart for each trait

Table 6: Farmers' preferences on different traits under lentil seed priming in baby trials, Myagdi

Trait	Shikhar			Simal			Shishir			Khajura Masuro-2		
	1 (%)	2 (%)	3 (%)	1 (%)	2 (%)	3 (%)	1 (%)	2 (%)	3 (%)	1 (%)	2 (%)	3 (%)
Ease to planting	16.7	83.3	0.0	8.3	91.7	0.0	16.7	83.3	0.0	41.7	58.3	0.0
Time to germinate	100.0	0.0	0.0	91.7	8.3	0.0	91.7	8.3	0.0	100.0	0.0	0.0
Plant stand after germination	33.3	66.7	0.0	33.3	66.7	0.0	50.0	50.0	0.0	16.7	83.3	0.0
Growth of the plant	58.3	41.7	0.0	41.7	58.3	0.0	16.7	83.3	0.0	25.0	75.0	0.0
Days to flowering	83.3	16.7	0.0	100.0	0.0	0.0	100.0	0.0	0.0	91.7	8.3	0.0
Weed problem	0.0	100.0	0.0	0.0	100.0	0.0	8.3	91.7	0.0	0.0	100.0	0.0
Insect/pest problem	8.3	91.7	0.0	0.0	100.0	0.0	0.0	100.0	0.0	0.0	100.0	0.0
Drought tolerance	8.3	91.7	0.0	0.0	100.0	0.0	8.3	91.7	0.0	16.7	83.3	0.0
Maturity	91.7	8.3	0.0	100.0	0.0	0.0	100.0	0.0	0.0	91.7	8.3	0.0
Grain size	16.7	83.3	0.0	0.0	100.0	0.0	8.3	91.7	0.0	0.0	100.0	0.0
Grain yield	91.7	8.3	0.0	100.0	0.0	0.0	83.3	16.7	0.0	83.3	16.7	0.0
Plan for next year planting	91.7	-	8.3	100.0	-	0.0	100.0	-	0.0	100.0	-	0.0

Note: 1 (%), 2 (%), 3 (%)–percent respondents reporting better, similar and worse result, respectively of primed seed over non-primed counterpart for each trait

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Table 7: Farmers' preference on different traits of lentil with soaked and non-soaked seeds in baby trials combined over locations

Trait	Shikhar			Simal			Shishir			Khajura Masuro-2		
	1 (%)	2 (%)	3 (%)	1 (%)	2 (%)	3 (%)	1 (%)	2 (%)	3 (%)	1 (%)	2 (%)	3 (%)
Ease to planting	29.2	70.8	0.0	29.2	70.8	0.0	29.2	70.8	0.0	45.8	54.2	0.0
Time to germinate	100	0.0	0.0	95.8	4.2	0.0	95.8	4.2	0.0	100.0	0.0	0.0
Plant stand after germination	37.5	62.5	0.0	54.2	45.8	0.0	54.2	45.8	0.0	29.2	70.8	0.0
Growth of the plant	75	25.0	0.0	66.7	33.3	0.0	50.0	50.0	0.0	45.8	54.2	0.0
Days to flowering	87.5	12.5	0.0	100.0	0.0	0.0	95.8	4.2	0.0	83.3	16.7	0.0
Weed problem	0.0	100.0	0.0	0.0	100.0	0.0	12.5	87.5	0.0	0.0	100.0	0.0
Insect/pest problem	4.1	95.9	0.0	0.0	100.0	0.0	0.0	95.8	4.2	0.0	100.0	0.0
Drought tolerance	33.3	66.7	0.0	37.5	62.5	0.0	41.7	54.2	4.2	29.2	70.8	0.0
Maturity	91.7	8.3	0.0	95.8	4.2	0.0	91.7	8.3	0.0	83.3	16.7	0.0
Grain size	54.2	45.8	0.0	41.7	58.4	0.0	45.8	54.2	0.0	33.3	66.7	0.0
Grain yield	91.7	8.3	0.0	95.8	4.2	0.0	83.3	16.7	0.0	75.0	25.0	0.0
Plan for next year planting	91.7	-	8.3	91.7	-	8.3	95.8	-	4.2	91.7	-	8.3

Note: 1(%), 2(%), 3(%) – percent respondents reporting better, similar and worse result, respectively of primed seed over non-primed counterpart for each trait

IV. Conclusion

At the same level of management, average grain yield increment was 13.6% and maximum of 19.4% was recorded in Shimal. Genotype and location specific effects of seed priming were observed. Varieties namely Shikhar and Shishir in Gorkha whereas Khajura Masuro-2 and Shishir in Palpa and Myagdi districts were preferred by farmers. Thus, farmers' preferences towards lentil variety was also found location specific. Varieties namely Khajura Masuro-2 (1507 kg ha^{-1}) and Shikhar (1408 kg ha^{1}) produced the highest grain yield in primed and non-primed condition, respectively. Mean days to flowering and maturity were recorded 3-4 and 3-6 days earlier of primed seeds compared to non-primed counterpart, respectively. Variety and location specific results on lentil seed priming were recorded and positive impacts of seed priming in grain yield and other quantitative traits were verified and demonstrated. Therefore, this technology should be promoted and disseminated widely using different varieties at various locations. Likewise, seed priming trials of improved varieties combined in one exercise provide exposure to new varieties and varietal selection options to growers.

Acknowledgements

Author would like to express his sincere gratitude to National Agricultural Research and Development Fund (NARDF) for funding this project. Regional Agricultural Directorate Pokhara, District Agriculture Development Offices of Gorkha, Palpa and Myagdi districts, Grain Legumes research Program, National Maize Research Program, LI-BIRD and collaborating farmers are sincerely acknowledged for their keen interest and contribution to the project activities.

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Global Journal of Science Frontier Research: D
Agriculture and Veterinary
Volume 18 Issue 3 Version 1.0 Year 2018
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Evaluation and Demonstration of Potchefstroom Koekoek Chicken in and Around Mehoni areas of Southern Tigray Zone, Ethiopia

By Atsbaha Hailemariam, Angesom Taye, Haftom Miglas, Challa Edea, Alemayehu Amare, Tadios Habte, Bethelihem Siyum & Dawd Ibrahim
Ethiopian Agricultural Research Institute

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Keywords: koekoek breed, survivability, egg production, scavenging, challenge, opportunity, perception and farmer's management.

GJSFR-D Classification: FOR Code: 300599



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Evaluation and Demonstration of Potchefstroom Koekoek Chicken in and Around Mehoni areas of Southern Tigray Zone, Ethiopia

Atsbaha Hailemariam [α], Angesom Taye [σ], Haftom Miglas [ρ], Challa Edea [ω], Alemayehu Amare [¥], Tadios Habte [§], Bethelihem Siyum [χ] & Dawd Ibrahim [ν]

Abstract- The evaluation and demonstration of Potchefstroom Koekoek Chicken were conducted in and around Mehoni Areas of Southern Tigray Zone, Ethiopia. Participant farmers were selected purposively based on their interest to construct poultry house; to cover other relevant poultry package costs, record the required data and to the most was identified by Mehoni Agricultural Research Center in Collaboration with the Raya Azebo Woreda Bureau of Agriculture and Rural Development Poultry experts based on the information given by national poultry research coordinating team (DZARC Poultry Team). The Survival of chicks during the first eight weeks of brooding using 40-watt bulb and traditional pot heater at farmers management condition were 82.86% (319 were survived out 385). On average about 94.56% of the chicken were survived to up to 2nd eight weeks of age while the overall survivability has attained to be 78.18% in the study areas. The average age at first egg laying was found to be 6.48 months and average weight of eggs at first laying and 5% production stage was 39.01g and 40.30g. Similarly, the average weight of egg of each participant farmers at 50% and Peak egg production stage was approved to be 43.93g and 48.77g, respectively. The average weight of male and female Koekoek chicken at 20 and 72 weeks of age was 1.40kg, 1.01kg, 2.70kg and 1.46kg respectively. The egg production per chicken has ranged from 124 to 186 with an average of 156.29 under scavenging farm condition. The average feed supplementation per chicken per day was 54.21g up to the intended production stage (72 weeks of age). The average profit of each participating farmers in the entire study period was 8927.34 Birr. Based on the result of the study, the major challenges were Transport stress and mechanical damage, Predator attack and flood, Shortage and cost of local and formulated feeds (drought existed), insufficient management(more emphasis to irrigation) and Diseases. On the other hand, the main opportunities of the Koekoek for the participants were income earning, survivability and adaptability of Koekoek and provision of training and experience sharing (capacity building). The participant farmers (71.42%) considered the Koekoek an excellent breed in the scavenging condition while other stakeholders ranked and put their perception with the accepted range (at least good). All in all, it can be concluded that the Koekoek breed has got acceptance in the areas and recommended to be disseminated to similar farming conditions with tackling ahead of the above-mentioned challenges.

Keywords: koekoek breed, survivability, egg production, scavenging, challenge, opportunity, perception and farmer's management.

I. Background and Justification

Poultry is the largest livestock group in the world estimated to be about 23.39 billion consisting mainly of chickens, ducks and turkeys (FAO, 2011; FAO, 2007) and has remained to be important in the improvement of food security and livelihood (Zemelak et al., 2016; Halima et al., 2007; Malago et al., 2014) and contributing about 28-30% of all animal protein consumed in the world (FAO., 2011; Shapiro *et al*., 2015). The chicken population in Ethiopia is estimated to be 59.5 million; 54.1 million are indigenous, 2.6 million exotic and 2.8 million hybrid and contributing 90.85%, 4.39% and 4.76% of the country's poultry population, respectively (CSA, 2016/17).

Poultry is necessary in supporting the livelihoods of poor farmers, consumers, traders and laborers throughout Ethiopia. Small-scale poultry rearing can be financially beneficial whatever the stock (indigenous or commercial) is used. Village poultry makes a substantial contribution to household food security throughout the developing world. Small-scale poultry is capable of contributing significantly to poverty alleviation and food security in remote and disadvantaged groups. Small-scale poultry production ranges from small semi-scavenging flocks of 10 to 30 indigenous breed birds in rural villages to 300 to 500 commercial improved breed birds managed with family labor in small-scale semi-commercial production systems. Small-scale poultry is a valuable asset to the local human population in many countries despite its relatively low productive performance of 40 to 60 eggs per year and 1.5 to 1.7 kg body weight at maturity. Chicken production has a major role in the economy of developing countries particularly to women. Several programs, in Ethiopia and else-where, have attempted to improve chicken production as a means to reduce poverty (Etalem *et al*., 2016-2030: Wondmeneh *et al.,*2011) and thereby ensuring a relatively safe level of

Author α σ ρ ω: Ethiopian Institute of Agricultural Research, Mehoni Agricultural Research center, P.O.Box 71, Maichew, Ethiopia.
e-mail: Atsbaba@yahoo.com
Author ¥ § χ ν: Ethiopian Institute of Agricultural Research, Debrezeit Agricultural Research Center, Bishoftu, Ethiopia.

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living standard which now becomes the current continental and global issue.

A recent study by Nigussie *et al*, (2010), ascertained that the significance of enhancing strong linkages and the need to follow modernly integrated and holistic technology packages dissemination approaches by certain socio-economic and physical environments.

There was no information weather Koekoek breeds of chicken could survive and produce using locally available feeds under farmer's management condition in and around Mehoni areas of Southern Tigray. Therefore evaluation and demonstration of this chicken breed in this area using locally available feeds (scavenging conditions) supported by supplementation was proposed as important to enhance the production and productivity of chicken in the study areas.

a) Objectives of the study

i. *General Objective*

To enhance a small scale commercial poultry production packages to improve rural livelihood and nutrition quality

a. *Specific Objectives*

To Evaluate and demonstrate the performance of the Koekoek chicken under farmers management condition

- To promote and disseminate the approved technology of the chicken to the users
- To increase the income of farmers secured from these chickens and their products
- To identify the challenges and opportunities for demonstration and dissemination of Koekoek breeds
- To see farmer's perception to the introduced improved dual-purpose Koekoek breeds

II. Materials and Methods

a) Description of the study area

Mehoni Town is located in Raya-azebo woreda of southern zone of Tigray region between latitude and longitude of $12^0$47'56" North and 39^0 38'38" East and it is about 112km far away from Mekelle city. The elevation of the area ranges from 694-2367m.a.s.l having an average elevation of 1700masl. The woreda has high livestock potential of above 250,000 including Cattle, Poultry, Sheep, Goat, Donkey, Mule, and Camel which shows potentiality of the Woreda for animal production. The temperature ranges from 16 to 25°C with rain fall ranging 490mm to 680mm (RWARDA, 2016/17).

The Mixed cropping system is mainly practiced in Raya Azebo Woreda. Sorghum, Maize, teff, barley, coffee, chat, fruits and vegetables are the most widely cultivated crops in the district. Chat (Munera chat), fruits and vegetables are important cash crops under farmer and investment condition.

b) Participant household selection

The Evaluation and demonstration were conducted in Raya Azebo Woreda in three Kebelle namely Tsigea, Genete and Kukufto. Participant farmers were selected purposively in collaboration with Raya Azebo Woreda. Accordingly poultry house, cover all the associated package costs and record the required data heater preparation., seven farmers were found fulfilled the required preconditions; house construction, feeding and watering materials, litter materials preparation and cost to buy chicks. Then the day-old Koekoek chicken was distributed among those farmers at their gate with starter ration and some medication materials.

c) Disease prevention and control

The health follows up aspect was undertaken using the Raya Azebo Woreda livestock health expert after participation in the training of the Koekoek technology. Plus, the trained health experts provided vaccination against poultry diseases such as Marex at day one, New castle/HB1 at day three, Newcastle/HB1 and Gumboro at day seven, Gumboro at day fourteen, Newcastle/Lasota at twenty one day, Gumboro and fowl typhoid at twenty seven day and Gumboro at thirty five day old.

d) Experimental Birds and their Management

A total of 385-day old chicks of "Potchefstroom Koekoek" breed were purchased from Debre Zeit Agricultural Research Center and transported to the three Kebeles (Tsigea, Genete, and KuKufto Kebelles) of Raya Azebo woreda and distributed to the selected farmers the same day at their gate. Each participant farmers have received 55 chicks. Brooding was done using 40- watt bulb and supported locally made pot heater. Data collection formats were prepared and given to each participant to record all the required data.

e) Data collected

The amount and type of feed offered, body weight gain, egg production, egg weight, disease symptom and medication cost, mortality and its cause, income from live chicken and egg sale.

f) Data analysis

The data were collected and recorded regularly using Microsoft Excel and SPSS software were used as tools for this data analysis. Besides; index method (Musa *et al.*, 2006) was used for data requiring ranking.

III. Result and Discussion

a) Survivability of Koekoek at Mehoni

The Koekoek chicken survivability rate from day old until the first eight weeks was observed to be 82.86% in the study areas. The Survivability rate from Day old until the 1st eight weeks age was 82.86% with a mortality rate of 17.14%. Plus, the survivability rate from

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the start of egg laying up to the 2nd eight weeks of age was 94.56 with a mortality rate of 5.64%. The average survivability of the Koekoek chicken has become 78.18% with a mortality rate of 21.72% among the participants in the study areas. This has shown that the a mortality rate in the first eight weeks was higher (17.14%) than from the 2nd eight weeks onwards (5.64%) (Table1). The performance evaluation and demonstration of Koekoek at Areka areas of SNNPR of Ethiopia has shown the survivability at be 79.8% and 93.1%, at 1st and 2nd eight weeks, respectively (Aman Getiso *et al.*, 2016).The survivability of Koekoek at Jimma zone of south western Ethiopia was 53.5% at farmer management condition at Mana district (Kassa *et al.*, 2016).

The survivability of the chicken in the 1st and 2nd eight weeks varied between farmers ranging from 43 (mortality=12) to 48 (mortality=7) and 43 (mortality=12) to 47 (mortality=8)) from the distributed 55 chicks/farmer, respectively. This difference in survivability among participant farmers was due to distant transport stress and mechanical damage, Predator attack (wild cat) (in Tsigea Kebelle), the variation in management (sticky flea in some) from farmer to farmer, diseases, and appropriate poultry house constructing problem (flood experienced in some) was observed as the major causes of mortality in this study.

Table 1: Survivability of Koekoek chicken at the age of 1st and 2nd eight weeks of age

Participants	Day old chicks distributed	Survivability in the 1st eight weeks	Survivability in the 2nd eight weeks	Overall survivability
BH	55	48	47	47
LK	55	45	43	43
MA	55	44	40	40
HH	55	48	45	45
EI	55	45	43	43
TA	55	46	43	43
MY	55	43	40	40
Total	385	319	301	301
Average (%)	100	82.86	94.56	78.18

b) *Number of pullets reached Age at first lay, age at first lay and weight of the egg*

The average number of Koekoek chickens reached first lay was reported to be 25.71 in the study areas. The average age of first laying recorded was 6.48 months, and the average weight of eggs at first laying was 39.01 g taking the egg weight at first day of lay at each participant (Table 2). Age at first egg laying of Koekoek chicken was 5.33 in Ada"a district while the average egg weight recorded was 48.84± 6.77g in Lume district (Desalew, 2012).

Table 2: Average age and weight of egg at first lay of Kokeoek under farmer's management

Participants	Number pullets reached AFL	Average age at first lay (Month)	Wt. of egg at first age of lay (g)
BH	28	5.7	41.9
LK	29	6.1	40.6
MA	22	6.8	38.4
HH	27	6.4	44.2
EI	24	6.9	35.8
TA	24	7.2	34.7
MY	26	6.3	37.5
Average	25.71	6.48	39.01

c) *Egg Weight at different production stages*

The average egg weight at initial laying stage (5% production stage) was observed 40.30g. This is almost similar to the weight achieved at Areka areas (40.2gm) (Aman *et al.,* 2016) but lower in weight than that of Dessalew (2012) which was (48.84± 6.77). As indicated in table 3, the increase in egg weight was observed as the production stage increases from 5% to peak stage (48.77gm). The average weight (48.77g) recorded at peak stage in this study under scavenging was slightly lower than that of DZARC evaluation (51.9g) under intensive production system.

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Table 3: Egg Weight at Different Production Stages

Participants	Wt. of at 5% of egg production (g)	Wt. of at 50% of egg production (g)	Wt. of at peak egg production (g)
BH	43.4	46.4	52.6
LK	41.7	43.2	47.8
MA	39.6	45.1	48.4
HH	45.9	47.2	51.7
EI	37.1	43.6	49.1
TA	36.4	41.3	46.5
MY	37.9	40.7	45.3
Average	40.30	43.93	48.77

d) Eggs/Day/chicken/participants and Eggs/hen/participant/year

The egg production ranges from 124 to 186 among the seven Koekoek chicken rearing participants under farmers management condition. Similarly, the average pullet numbers of the participant farmers were 25.71 producing on average 0.54 eggs/day with average egg production of 156.29 in the entire annual production (52 weeks of production phase).

Table 4: Number of pullets reached egg laying, Eggs/Day/chicken and Eggs/hen

Participants	Pullet reached for egg laying	Eggs/day/chicken	Eggs/hen/year
BH	28	0.65	186
LK	29	0.59	172
MA	22	0.55	158
HH	27	0.57	165
EI	24	0.47	136
TA	24	0.53	153
MY	26	0.43	124
Average	25.71	0.54	156.29

e) Body weight gain

The average body weights recorded in the first twenty weeks of age was 1.01kg in the case of the female chicken and 1.40kg for the males. Besides, the average body weight gain at 72 weeks of age was 1.46 for the female and 2.70 for the male in the study areas (Table 5).

Table 5: Body weight gain of chicken at the different stage of growth

Participants	Female at 20 weeks in kg	Male at 20 weeks in kg	Female at 72 weeks in kg	Male at 72 weeks in kg
BH	1.12	1.57	1.61	2.93
LK	1.08	1.52	1.54	2.82
MA	1.05	1.43	1.47	2.68
HH	1.09	1.36	1.51	2.79
EI	0.967	1.29	1.38	2.58
TA	0.938	1.38	1.44	2.45
MY	0.848	1.24	1.26	2.41
Average	1.01	1.40	1.46	2.70

f) Feed Supplementation

A balanced ration provided from DZARC was fed to the chicken in the first eight weeks of age. After fully utilization of this commercial balanced ration, the farmers was advised to buy feed ration from nearby feed processing plants (Bokra union at maichew) and/or prepare feeds from locally available feed materials which include maize, sorghum, tomato, potato, wheat bran, groundnut cake, vegetables, kitchen leftovers, salt and lime stone based on different stages of development (grower and layer stages). The overall average amount of supplemental feed used in this study were recorded 54.21g/day/chicken irrespective of the two phases (grower and layer stages) which is bellow their requirements both in quantity and quality (Table 6). Scavenging was the major means of satisfying their nutrient requirements enabling to express their natural behavior such as dust bathing besides getting access to insects, worms and other leftovers around the homestead in the study areas.

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Table 6: Amount of feed supplementation for Koekoek in the study areas

Participants	The range of supplemented feed(g/bird/day)	The average of supplementation of feed in each participant (g/bird/day)
BH	50-75	67.00
LK	40-70	60.25
MA	40-65	50.00
HH	40-70	55.00
EI	35-70	52.5
TA	30-60	50.25
MY	35-50	44.5
Average		54.21

g) Perception of Various stakeholders to the Koekoek technology in the study areas

Most of the participant farmers were glad about the delivery of the Koekoek technology with 71.42%, 14.29%, 14.29% scored excellent, very good and good, respectively. However, the farmers complained about the color of the breed (feel as if interbreed with wild birds) intending more awareness creation and the continuous sources of the Koekoek breed and poultry feed also mattered. The Zonal and woreda heads and the experts were in doubt about the continuity and availability of the breed and poultry feeds.

The zonal and agricultural office heads and experts had explained as excellent (50.20%), very good (29.40%) and good (23.40%) showing their opinion as accepted to the Koekoek technology delivery and demonstration in the study areas. Similarly, the Tigray agricultural research institute Alamata agricultural research center has agreed to the delivery and demonstration of the Koekoek technology at farmer management conditions. Finally, a The Ethiopian Broadcast and Tigray TV participant were happy with the technology delivery and opinion of the participant farmers during their interview about the Koekoek technology and had disseminated the technology through media and other information delivery sources (websites) (Table 7).

Table 7: Perception of Various Stakeholders to the Koekoek technology

Stakeholders	Perception of stakeholders			%
	Excellent	Very good	good	
Participant farmers	71.42	14.29	14.29	100
Zone and woreda administration offices	16.66	66.68	16.66	100
Zone and woreda agricultural office	50.20	29.40	23.40	100
Agricultural research center (Alamata)	2.10	75.80	22.10	100
EBC and TV(Media)	12.70	62.10	25.20	100

h) Partial budget analysis

In computing the partial budget analysis the feed, medication, chicken house maintenance and chicken cost were considered as variable costs whereas the sale of live chicken, eggs and the existing chicken till the time of this data collected were used as an income source. Based on the listed variable costs and the income earned the average income generated per individual farmers were 8927.35 birrs. This was in agreement with the finding at Jimma and Areka that the Koekoek was profitable at farmer management conditions with the reported average profitability of 2731.02 and 1048.90 birr respectively though there was much difference in magnitude of profitability in the study area (Kasa *et al*., 2016: Aman *et al*.,2016). This could be due to the collaboration and improved perception of the stakeholders especially the participant farmers and to the most their voluntarism for the advice given by the researchers at Mehoni Areas. This might also be due to improved management and attractive market for the sale of the live chickens and eggs of the Koekoek breeds available in the study areas.

The change in net income (ΔNI) was calculated as the difference between the change in total return (ΔTR) and the change in total variable costs (TVC)

ΔNI= ΔTR - ΔTVC

ΔNI=96155.40-33664 Ethiopian Birr

ΔNI=62491.40Ethiopian Birr

Average profit/participant=62491.4÷7

Average profit/participant =8927.35 Ethiopian Birr

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Table 8a: List and amount of Variable cost for Koekoek chicken technology in Mehoni areas

	List of variable costs					
Participants	Unit	House maintenance	Chick purchase	Feed cost	Medication cost	Total
BH	Birr	1514	300	3550	573	5937
LK	Birr	1007	300	3250	517	5074
MA	Birr	935	300	2750	548	4533
HH	Birr	803	300	2850	496	4449
EI	Birr	689	300	2570	479	4038
TA	Birr	746	300	2630	394	4070
MY	Birr	685	300	2380	398	3763
TVC	Birr	5579	2100	22080	3405	33664
Average						4809.14

Table 8b: List and amount of income earned from Koekoek chicken technology in Mehoni areas

	Lists of incomes						
Participants	Unit	Sale of cocks	Sale of hens	Sale of eggs	Home slaughtered price of chickens	Home consumed price of eggs	Total
BH	Birr	2695.95	2280	12630	380	429	18414.95
LK	Birr	1567.9	2125	12220	340	275	16527.9
MA	Birr	1516.7	1260	8525	280	181.5	11763.2
HH	Birr	1455.6	1800	10867.5	225	297	14420.1
EI	Birr	1394.7	1540	7917.5	140	266.75	11258.95
TA	Birr	1378.9	1650	6855	150	285	10318.90
MY	Birr	1346.4	1610	7825	210	235	11226.40
TR	Birr	11356.15	12265	66840	1725	1969.25	96155.40
Average	Birr	1622.31	1752.14	9548.57	246.43	281.32	13736.49

Depending on the result of this study, the Koekoek chicken has encountered with some difficulties and causes of mortality that are hindering with success desired in the technology demonstration and dissemination. The Main challenges and causes in Koekoek rearing in the areas arise from long transport stress and mechanical damage, predator attack and flood, shortage and cost of local and formulated feeds, insufficient management and diseases/Newcastle (Table 8).

Table 9: Major Challenges/causes of Koekoek technology mortality at Mehoni Areas

Challenges/Causes	1	2	3	4	5	Overall rank
insufficient management	-	-	19.4	50.2	30.40	4
shortage and cost of both local and formulated feeds for Koekoek	21.4	35.7	42.9	-		3
Transport Stress and mechanical damage	64.3	14.3	21.4	-		1
Predator attack and flood	14.3	50	35.7	-		2
Disease/Newcastle	2.40	4.60	3.10	29.20	60.70	5

According to the study, the imminent opportunities for participants of Koekoek technology in the study areas include delivery of Koekoek technology and income earning, adaptability and survivability of Koekoek (Majority) and provision of training/capacity and experience sharing before and after distribution of the Koekoek technology in collaboration of Mehoni Agricultural research center and Debrezeit agricultural research center (Table 9).

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Table 10: Major opportunities of Koekoek technology participants at Mehoni Areas

Opportunities	1	2	3	Overall rank
Delivery of Koekoek and income earning	56.2	15.4	28.4	1
Adaptability and survivability of Koekoek	27.6	46.2	26.2	2
Provision of training and experience sharing	16.2	38.4	45.4	3
Total	100	100	100	

IV. Conclusion and Recommendation

The survival of chicks during the first Eight weeks of brooding using 40-watt bulb and traditional pot heater at farmers management condition was 82.86% (319 were survived out 385). The average age at first egg laying was found to be 6.48 months, and the average weight of eggs at first laying and 5% production stage was 39.01g and 40.30g. Similarly, the average weight of egg of each participant farmers at 50% and Peak egg production stage was approved to be 43.93g, and 48.77g, respectively. The average weight of male and female Koekoek chicken at 20 and 72 weeks of age was 1.40kg, 1.01kg, 2.70kg and 1.46kg respectively. The egg production per chicken has ranged from 124 to 186 with an average of 156.29 under scavenging farm condition. The average feed supplementation per chicken per day was 54.21g up to the intended production stage (72 weeks of age).

The average profit of each participating farmers in the entire study period was 8927.35 Birr. Depending on the result, the main challenges were Transport stress and mechanical damage, Predator attack and flood, Shortage and cost of local and formulated feeds (drought existed), insufficient management(more emphasis to irrigation) and Diseases/Newcastle. On the other hand, the major opportunities of the Koekoek for the participants were income earning, survivability and adaptability of Koekoek and provision of training and experience sharing (capacity building). The participant farmers (71.42%) considered the Koekoek as an excellent breed in the scavenging condition while other stakeholders ranked and put their perception with the accepted range (at least good). Therefore, it can be concluded that the Koekoek breed has got better acceptance and has to be disseminated to similar farming conditions with tackling ahead of the afore mentioned challenges.

Acknowledgments

The authors are grateful to All Mehoni and Debrezeit Agricultural Research Center Staffs for supporting both in technically and financially. We also acknowledged the Tsigea, Genete and Kukufto Kebeles leaders and agriculture office livestock experts for their support during the research works and all participant farmers of Raya azebo woreda who actively participated in this work are heartfelt acknowledged and respected at large.

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Appendix





A/Preparation and distribution of Koekoek chicks

B/Participation of woman in Koekoek demonstration





C/Sample of Weighing of Koekoek at Mehoni areas





D/Sample of egg production of participating farmers from the distributed Koekoek chickens

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E/Capacity building (Provision of training on Koekoek production and management) of participating farmers



F/The observation the status of Koekoek breeds followed by discussion with the participants (exposure visit)

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Global Journal of Science Frontier Research: D
Agriculture and Veterinary
Volume 18 Issue 3 Version 1.0 Year 2018
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Technical Efficiency and its Determinants in Smallholder Tea Production: Evidence from Nyamira and Bomet Counties in Kenya

By Josiah M Ateka, Perez A. Onono & Martin Etyang
Kenyatta University

Abstract- The smallholder tea sub-sector in Kenya has enjoyed relative growth in acreage, output, and number of growers since its inception in the early 1960s, but productivity has remained low. There are huge differentials between actual and potential yields suggesting underlying production inefficiencies. This study estimated the level of technical efficiency and analyzed its determinants among tea farmers from two selected counties in Kenya. Using data from a sample of 525 farm households, the non-parametric data envelopment analysis was applied to estimate technical efficiency scores. The scores were then regressed on a set of explanatory variables to establish their influence on efficiency. The average efficiency score of 0.46 indicates that overall productivity in Kenya's smallholder tea sub-sector is low but has a potential to increase if most of the farmers can adopt practices of the frontier farms. The intensity of family labor use, farm size, age of the tea farm, education level of the household head, access to extension services through the farmer field schools, and the sale of green leaf through alternative marketing channels have a significant influence on levels of efficiency.

Keywords: *smallholder, tea production, Technical efficiency, determinants, fractional regression.*

GJSFR-D Classification: *FOR Code: 070199*

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Technical Efficiency and its Determinants in Smallholder Tea Production: Evidence from Nyamira and Bomet Counties in Kenya

Josiah M Ateka [α], Perez A. Onono [σ] & Martin Etyang [ρ]

Abstract- The smallholder tea sub-sector in Kenya has enjoyed relative growth in acreage, output, and number of growers since its inception in the early 1960s, but productivity has remained low. There are huge differentials between actual and potential yields suggesting underlying production inefficiencies. This study estimated the level of technical efficiency and analyzed its determinants among tea farmers from two selected counties in Kenya. Using data from a sample of 525 farm households, the non-parametric data envelopment analysis was applied to estimate technical efficiency scores. The scores were then regressed on a set of explanatory variables to establish their influence on efficiency. The average efficiency score of 0.46 indicates that overall productivity in Kenya's smallholder tea sub-sector is low but has a potential to increase if most of the farmers can adopt practices of the frontier farms. The intensity of family labor use, farm size, age of the tea farm, education level of the household head, access to extension services through the farmer field schools, and the sale of green leaf through alternative marketing channels have a significant influence on levels of efficiency. To exploit the existing potential for increasing productivity the smallholders should adopt labor saving technologies and replant to replace the aging tea farms. Further, government should implement actions to promote consolidation of small tea farms and expand the farmer field school extension programs to reach more farmers.

Keywords: smallholder, tea production, technical efficiency, determinants, fractional regression.

I. Introduction

Tea production in Kenya has expanded rapidly over the years with significant contribution to the country's economy. The industry accounts for about 5 percent and 25 percent of the country's GDP and foreign exchange earnings, respectively (Republic of Kenya, 2017). The sector, directly and indirectly, supports over 5 million farm families, making it one of the leading sources of livelihood in the country (The Republic of Kenya, 2015). Globally, Kenya is among the four (4) leading producers; alongside China, India and Sri Lanka, who collectively account for over 75 percent of the global tea production (International Tea Committee, 2013). Production is mainly carried out in the highlands on the eastern and western sides of the Rift Valley from 1500 - 2700 meters above sea level (Kagira *et al*., 2012; Tea Board of Kenya, 2014). The production structure is a dual system comprising of both large-scale plantations and the smallholder sub-sectors (Ogise *et al.,* 2008). The smallholder subsector is dominant with more than 500,000 farmers producing about 60 percent of the industry output. It is reported to be the largest and most successful smallholder schemes in the world (Kagira *et al*., 2012; Onduru *et al*., 2012). From the early 1960s, the planted area and output from the smallholder tea subsector are as shown in figure 1.

Author α σ ρ: Kenyatta University. e-mail: onono.perez@ku.ac.ke

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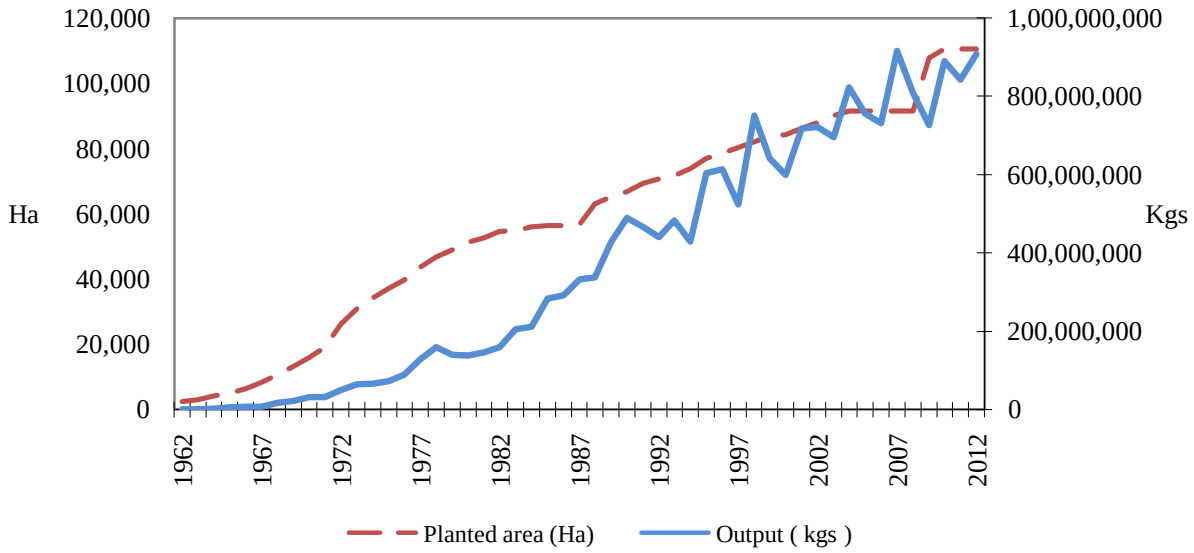

Figure 1: Trends in planted area and output in Kenya's Smallholder tea sub-sector from 1962-2012 (AFA Statistics, 2013)

As shown in figure 1, the acreage under tea expanded from less than 3000 hectares in 1962 to over 110,000 hectares in 2012; while production rose from about 1.3 million kilograms to over 900 million kgs of green leaf in the same period (Republic of Kenya, 2016). The expansion, especially in the earlier years of independence, is attributed to the land distribution policies, well-functioning extension systems, adoption of recommended technologies, attractive world market prices and release of high yielding clones (Mwaura *et al.,* 2005; Mbeche, 2012; Republic of Kenya, 2016).

Despite its growth and immense contribution to the national economy, productivity within the smallholder tea sub-sector remains low. The mean annual yield is 1785 kgs of processed tea per hectare (kgs pt/ha) which is far less than the 3038 kgs pt/ha in plantation sub-sector and an industry potential of 4745 kgs pt/ha (Kamau, 2008; Tea Research Foundation of Kenya (TRFK), 2013). Analysis of industry trends, further show impressive growth in yields in the earlier years of independence, but later setbacks were realized. The trend in Kenya's Smallholder tea Productivity in the period 1963-2011 is shown in figure 2.

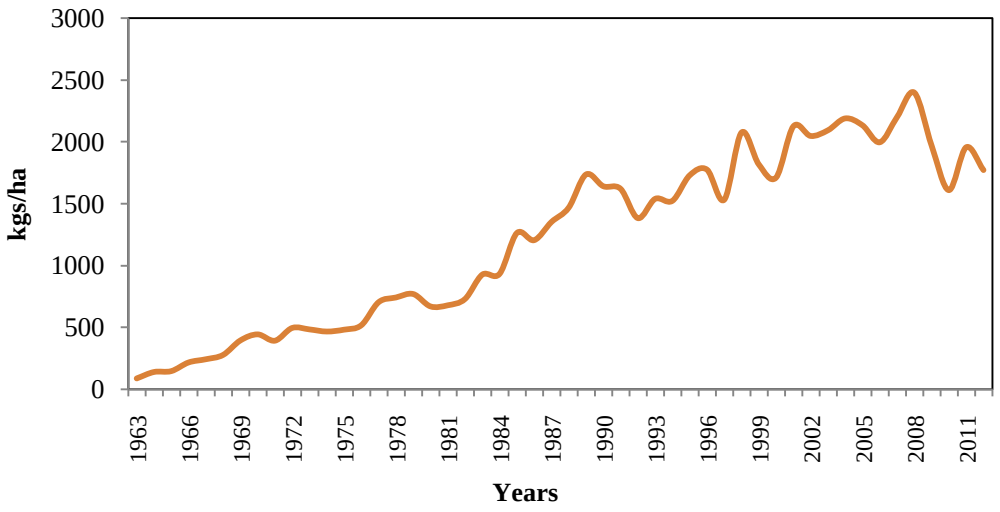

Figure 2: Kenya's Smallholder tea Productivity in the period 1963-2011(Kamau, 2008; KTDA Statistics, 2013)

As shown in figure 2, there was steady and consistent increase in yields per hectare from the 1960s through to the 1980s. However, through the 1990s and 2000s, yield fluctuations, interposed by stagnation and declines were witnessed. The unimpressive trend in tea productivity coupled with the differences between actual

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and potential yields, point to existence of inefficiencies and, therefore, a potential to increase productivity. Enhancing efficiency can be an essential factor of productivity growth in the sub-sector since tea cultivation requires high investments and involves very high switching costs (Republic of Kenya, 2010). This study therefore estimated the level of technical efficiency (TE) and analyzed its determinants among smallholder tea farming households in Bomet and Nyamira counties of western Kenya. The two counties are among the leading tea producing counties in Kenya and provided a fair representation of the tea growing areas in western Kenya. The counties have relatively similar agro-ecological conditions, which was necessary to minimize the effects of geo-climatic variability in the analysis of efficiency.

II. Methodology

a) Theoretical Framework

Estimation of TE in this study follows a framework based on agricultural production theory where a typical tea farming household is assumed to use owned and purchased inputs to produce tea and other farm outputs. The household's production technology, therefore, utilizes a vector of inputs; $(x_1,...,x_n) \in \Re_+^n$ to produce a non-negative vector of outputs; $(y_1,...,x_m) \in \Re_+^m$. The household's production possibility set (PPS) which is the collection of all the feasible input-output vectors is the subset T of the space $\Re_+^{m+n}$ is therefore represented as

$$T = \{(YX) : X \text{ can produce } Y\} \in \Re_+^{m+n} \quad (1)$$

The tea farming household may select any input-output configuration in T as its production plan. Since it faces an optimization problem, based on inputs and outputs, analysis of the performance of a tea farm requires specification of a technical relationship that reflects the choice combination of inputs that leave the farm with the most output given its feasible output set (Varian, 1992). The production function which theoretically represents the maximum output that can be obtained from a given set of inputs (Jehle and Reny, 2011), can be specified as

$$Y = F\left(X^{t^i}, Z^{t^i} \middle| \sum_i Z^{t^i} \le \bar{M} \right) \quad (2)$$

Where, *Y* is a vector of agricultural outputs, *X* and *Z,* are vectors representing purchased and farmer-controlled inputs which typically include fertilizer, labor, and land respectively. The superscript, t^i reflects the seasonality and sequential nature of agricultural production stages imposed by biological characteristics. Such a recursively separable structure of the production process implies for instance that labor applied for pre-harvest activities such as planting and weeding is separable from labor applied to harvesting activities. The vector, *M* represents the maximum use or availability of services made possible by the fixed stock of farmer-controlled inputs in each stage of the production process. Equation 2 emphasizes the fact that there are some unique features that typify agricultural production and that while there are some parallels with other sectors of the economy, the extent to which the features occur in agriculture has implications on how they can be represented empirically (Debertin, 2002; Karagiannis, 2014).

The behavioral relationship between inputs and output can further be characterized by returns to scale (RTS) in production. The farm's technology can exhibit constant returns to scale (CRS) or variable return to scale (VRS). In CRS production technology, a given percentage increase in inputs leads to the same percentage rise in output. However, in the VRS, a given percentage increase in inputs could lead to a less or more than proportionate increase in output (Daraio and Simar, 2007). Representation of returns to scale in agricultural production analysis indicates whether any efficiency gains can be obtained by adjusting the scale of operation of a farm (Tolga *et al.,* 2009). The theoretical premise is that a production function represents the boundary of the PPS and a farm operating on its production function could be considered to be efficient in the use of its inputs. In this context, efficiency in tea production reflects the choice of production technology that leaves the farm with the most output given its possible output set. This corresponds to the characterization of technical efficiency (TE) in traditional economic theory.

The study followed the framework developed by Farell (1957) in which inefficiency is theorized as the extent to which a farm's inputs can be contracted towards the boundary of the PPS represented by the idealized isoquant such as the CC' shown in figure 3. The isoquant assumes a production technology of the firm characterized by smooth, continuously differentiable, constant returns to scale (CRS) and a strictly quasi-concave production function.

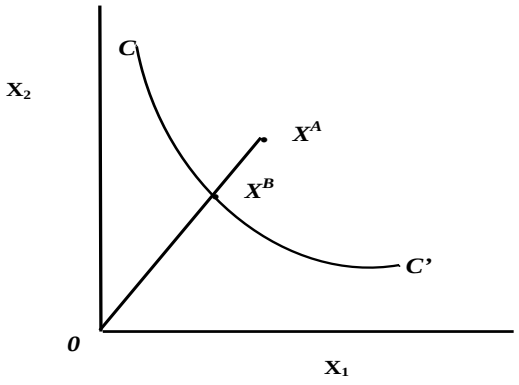

Figure 3: Conceptualization of TE Based on an Idealized Isoquant

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The input vectors X^A and X^B represent the combination of inputs used by two farms A and B to produce a unit of output. If the curve CC' represents the efficient unit isoquant (EUI), then X^B represents an efficient input set for producing a unit of output while X^A is an inefficient input set. According to Farrell (1967), the level of TE of farm A would be represented by the fraction $\frac{OX^B}{0X^A}$ since it represents the proportion of inputs that an efficient farm (in this case farm B) uses to produce the same level of output (Farrell, 1957). In this manner, the measure of TE shows the possible proportional reduction of inputs that can be achieved for farm A without any reduction of its output.

Technical efficiency conceptualized in this context can be estimated using data envelopment analysis (DEA), a non-parametric linear programming (LP) specification that involves comparison of observed producers with each other. DEA is premised on the existence of a production frontier or a best practice technology and variations in performance in the transformation of inputs and outputs among producers in an industry. It involves fitting a linear quasi convex hull around the input –output data of observed farms then determining TE as each farm's distance from it (Daraio and Simar, 2007). The assumption is that any deviations from the hull are attributed to inefficiency.

Using the efficiency scores obtained from DEA, variations in the scores across small holder tea farmers can then be analyzed. Variation in the TE scores are thought to be due to agent and structural factors (Ogada *et al.,* 2014) consisting of policy and institutional variables, the internal structure of the farm and agency factors such as the levels of human capital and experience of the farmer (Yoshiko, 2011; Kiprono, 2013). Policy and institutional factors in tea production include the marketing channels for sale of green leaf, access to extension and credit services. The farm specific factors include farm size, tea variety planted, location of the farm and age of tea bushes. The farm household characteristics that could affect efficiency include age of the farmer, household type, labour structure in tea farming and education level attained by the household head.

b) Empirical Models and Estimation Procedures

i. *Estimation of Technical efficiency in smallholder tea farms*

The study estimated the TE of smallholder farms using the DEA model under an assumption of a VRS production technology to allow the determination of scale inefficiencies. The linear programming VRS DEA model was specified as;

$$\underset{\theta,\lambda}{Minimize}\ \theta \tag{3}$$

Subject to

$$-Y^q + \lambda Y \geq 0 \tag{4}$$

$$\theta X^q - \lambda X \geq 0 \tag{5}$$

$$\sum_{n=1}^{n} \lambda = 1 \tag{6}$$

where θ represents the proportion of the farm's input bundle needed to produce its own output, Y^q is tea output of the qth farm, X^q is the level of the input set used on q^{th} farm for tea production (including fertilizer, labour and land) and λ is the weight given to each farm in the construction the frontier. The model is interpreted as seeking a frontier farm that can produce at least the output of the qth farm, using the smallest possible multiple of its inputs. It is solved n times to obtain efficiency scores for all the farms in the sample.

The characterization of the nature of the returns to scale (RTS) was achieved by estimating an additional non-increasing returns to scale (NIRS) DEA model in which the convexity constraint in equation 6 was replaced with

$$\sum_{n=1}^{n} \lambda \leq 1 \tag{7}$$

The RTS of the individual tea farms in the sample was then determined by checking whether the TE scores obtained from the VRS and NIRS models were equal. A farm is considered to experience decreasing or increasing returns to scale if the TE score obtained from NIRS and VRS DEA models are equal or not equal, respectively (Banker *et. al.*,2004). The final step in the analysis of TE involved an extension of the VRS DEA model to account for input slacks whose values indicate the amount by which the constraints in the model are not fully satisfied. The slacks therefore, represent the amount by which inputs are overused relative to the efficient farms (Padilla-Fernandez and Nuthall, 2012).

ii. *Determinants of technical efficiency in smallholder tea farms*

Analysis of the effect of the various factors on TE was evaluated by applying the fractional Regression Model (FRM) proposed by Papke and Wooldridge (1996; 2008) to model bounded and fractional dependent variables. The model was considered appropriate for analyzing DEA scores since it is based on a functional form that imposes the restriction that the conditional mean of the dependent variable is bounded within the interval [0, 1]. The model was specified as;

$$TE_i = g(z)[X_j\beta] + \varepsilon_i \quad \text{for i} = 1,2,\ldots,N \text{ and } j = 1,2,\ldots,11 \tag{8}$$

where, the vector X consist of institutional and market factors as well as farm characteristics hypothesized to be correlated with TE and $g(.)$ is some nonlinear

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function satisfying the condition that $0 \leq g(z) \leq 1$ for all $z \in R$ (Papke and Wooldridge, 1996). The function $g(.)$ is typically modeled as a cumulative distribution function and was estimated as standard normal distribution functions.

c) Research design

The study employed a non-experimental cross-sectional research design to achieve its objectives. The design allowed for the collection of information on household farm, demographic, socioeconomic and institutional characteristics that was necessary for the analysis of efficiency. Data for the study was collected from a cross sectional survey of 525 sampled smallholder farmers from a target population of 528, 817 smallholder tea farming households spread across Bomet and Nyamira Counties of Kenya. The multi-stage random sampling procedure was used whereby the two counties were purposively selected, being among the leading tea producing counties in Kenya and present a fair reflection of the variability in farm size across the tea growing areas in Kenya (KTDA, 2013). Stratification of counties into administrative sub-counties was done followed by a random selection of one tea growing sub-county from each county. Two administrative divisions were randomly selected from the selected sub-counties from which farming households for the survey were selected randomly. The sample size was proportionately distributed across the selected divisions based on the population of tea farming households in each division. Data was obtained from the sampled farming households by the interview method guided by a structured questionnaire in the period between December 2015 and March 2016.

d) Study variables and their measurement

The variables covered in the study were defined and measured as indicated in table 1.

Table 1: Definition and Measurement of Variables

Variable	Definition and measurement
Output:	The quantity of harvested tea (Green leaf) in kilograms per year.
Education:	The education status of the household head measured in terms of the highest level of education attained (1= primary, 2 = secondary, 3 = tertiary 4= university)
Labour	The quantity of labour used in tea production activities, measured in man-days per year with one man-day equivalent to 6 hours
Fertilizer	The quantity of fertilizer in number of 50 kilogram bags applied on the tea farm per year
Farm size:	The total area under tea crop in acres
Labour structure	The proportion or percentage of family labour applied in tea farming
Gender	The sex of the household head, measured by a dummy: 1 if male, 0 otherwise.
Extension services (FFS)	This is participation of the household in the farmer field school (FFS) program, measured as a dummy: 1 if participating in FFS, 0 otherwise.
County dummy	Used to account for the fixed regional effects: 1if Bomet county, 0 otherwise
Age of the tea farm:	Captured how old the tea bushes are, measured by the number of years since current tea crop/bushes were establishment or planted.
(ATMC participation)	This is participation of the household in an Alternative tea market channel (ATMC) measured using a dummy: 1 for participation in ATMC, 0 otherwise.

III. Empirical Results and Discussions

a) Descriptive Summaries on Data

The descriptive summary of the data on study variables is presented in table 2 for continuous variables.

Table 2: Summary Statistics for the Continous Variables

Variable	Total sample (n = 525)		Bomet	Nyamira	
	Mean	Std dev	Mean	Mean	t score
Farm size (acres)	1.3	1.1	1.6	1.2	3.8
Fertilizer per farm (bags)	4.6	3.8	5.8	3.9	5.8
Labor per farm (Mandays)	163.9	138.5	136.2	180.1	3.5
Labor structure (%)	58.2	45.5	62.3	55.7	1.6
Age of farm (Years)	27.0	14.9	21.8	30.1	6.4
Output per farm (Kgs)	3208.3	3019.8	5035.9	1820.0	14.0
Yields per farm(kgs/acre)	2745.9	2067.6	3907.9	2064.9	10.9
Distance to market (kms)	2.90	2.73	2.84	2.93	0.39

The differences in the means are significant for values of t above 1.8

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The summary shows that the operated tea farms within the sample were relatively small ranging between 0.1 and 7 acres with a mean of 1.3 acres. This was expected in the context of on-going subdivision of farms that is prevalent in the areas covered by the study (Republic of Kenya, 2014b). The average farm size under tea in the two counties was 1.6 and 1.2 acres for Bomet and Nyamira County, respectively. The statistically significant difference in the mean size of tea farms between the two counties implies that that smallholder tea farms in Bomet are relatively larger than in Nyamira, which is consistent with the demographic structure in the two counties (Republic of Kenya, 2009).

Apart from land, fertilizer and labour are the other key inputs used in tea production. The average amount of fertilizer applied was 4.6 bags of 50 kilogram (kgs) fertilizer per farm with a standard deviation of 3.8 bags. This level of fertilizer use is below the recommended annual rate of 5 bags per acre (TRFK, 2002). The average annual labour utilized per farm in the overall sample was 163.9 man-days compared to a mean of 136.2 man-days for Bomet County and 180.1 man-days for Nyamira County. The summary indicates that while the smallholder farmers in Bomet County used more fertilizer, those in Nyamira had higher levels of labour use. In terms of the structure of labour, on average 58.2 percent of the labour used was supplied by the household while the remaining 41.8 percent was hired. The difference in the average proportion of household labour between the two counties was statistically insignificant, which indicates that the labour structure in the two counties was relatively similar.

At the farm level, the age of the tea farm is an important characteristic since aging tea plantations are associated with decline in tea productivity (Kamau, 2008). The average age of tea bushes in the sample was 27 years. Comparatively, the results revealed that the difference in the mean age of tea bushes in the two counties was statistically significant. The mean age was 21.8 years for Bomet and 31.1 years in Nyamira County, which indicates that tea bushes in Bomet County were relatively younger and therefore expected to be more productive than those in Nyamira County.

With regard to the tea output, the mean annual output per farm was 3208.3 kgs of tea with a standard deviation of 3019.8 kgs and a range of 100 kgs to 14400 kgs. The mean annual tea output per farm in Bomet was 5035.9 kgs compared to 1820 kgs for Nyamira County. The mean annual yield for the overall sample was 2745.9 kgs per acre compared to 3907.9 kgs and 2064.9 kgs per acre for Bomet and Nyamira County, respectively. This shows that farmers in Bomet County had higher annual yields per acre than their counterparts in Nyamira County a difference that could be attributed to the application of higher fertilizer rates, younger and more productive tea bushes and differential utilization of agricultural credit. The average distance from the farm to the nearest market was 2.9 kilometres with a standard deviation of 2.7 kilometres.

Summary statistics for categorical variables are presented in table 3 which shows that 84.2 percent of the sampled households were headed by males while the remaining 15.8 percent were female headed. On education, 45.3 percent of household heads had attained primary level education, 40.2 percent had secondary level education, 9.6 percent had attained college education while only 5 percent had university education. The latter indicate that majority of the sample farmers had no training at the higher education level.

Table 3: Summary Statistics for the Categorical Variables

Variable	Measure	Combined		Bomet		Nyamira		Z test
		Freq	%	Freq	%	Freq	%	Z score
Gender	Male	442	84.2	168	86.6	274	82.8	1.16
	Female	83	15.8	26	13.4	57	17.2	1.16
Education	Primary	238	45.3	91	46.9	147	44.4	0.55
	Secondary	211	40.2	70	36.1	141	42.6	1.47
	Tertiary	50	9.6	24	12.4	26	7.9	1.70
	University	26	5.0	9	4.6	17	5.1	0.25
Tea variety	Yes	315	60.0	133	68.6	182	55.0	3.06
	No	210	40.0	61	31.4	149	45.0	3.06
Extension (FFS)	Yes	277	52.8	107	55.2	170	51.4	0.84
	No	248	47.2	87	44.8	161	48.6	0.84
market channel	KTDA	334	63.6	109	56.2	225	68.0	2.71
	ATMC	191	36.4	85	43.8	106	32.0	2.71

The differences in the means are significant for values of t above 1.8

Given that at the farm level, the variety of tea planted can have significant influence on yields, the study considered whether the household had planted improved clonal varieties or the non-improved seedling tea varieties. The summary in table 3 show that 60.0 percent of the sampled households had planted

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improved tea varieties. The proportion of farms with the improved clonal varieties in Bomet County was 68.6 compared to 55.0 percent in Nyamira County. The higher rate of adoption observed in Bomet County may to some extent explain why the county had achieved better performance in terms of tea yields. The higher adoption rate of tea clones in Bomet County could be attributed to county's proximity to the Tea Research Institute (TRI) which is responsible for the release of tea clones to farmers and is.

The summary also indicates that 52.8 percent of the sampled farmers had access to the FFS extension systems with no significant difference in the two sampled counties. The study also considered whether the household exclusively sold its green leaf to a Kenya Tea Development Authority (KTDA) factory or used alternative market channels (ATMCs). The ATMCs considered in the study included the sale of green leaf through middlemen or the multinational and private tea factories. The summary reveals that the KTDA channel was used by majority of the farmers and accounted for nearly 63.6 percent of the sample. Therefore only 36.4 percent of the farmers used the alternative markets channels. However at each county level, 43.8 percent of farmers in Bomet used the alternative channels compared to only 32 percent in Nyamira County. The results imply that the ATMC which is an outcome of the liberalization of the tea sector has since grown and currently commands a sizable share of the green leaf market.

b) Technical Efficiency scores for the sampled smallholder farmers

A summary of the TE scores obtained for each of the sampled farms is presented in table 4

Table 4: Frequency Distribution of The TE scores for sampled farms

TE scores	Combined sample			Bomet			Nyamira		
	N	%	Cum %	N	%	Cum %	N	%	Cum %
0- 0.10	4	0.8	0.8	0	0.0	0.0	4	1.2	1.2
0.11-0.20	62	11.8	12.6	10	5.2	5.2	52	15.7	16.9
0.21-0.30	93	17.7	30.3	19	9.8	15	74	22.4	39.3
0.31-0.40	91	17.3	47.6	27	13.9	28.9	64	19.3	58.6
0.41-0.50	98	18.7	66.3	39	20.1	49	59	17.8	76.4
0.51-0.60	50	9.5	75.8	28	14.4	63.4	22	6.6	83.0
0.61-0.70	42	8.0	83.8	25	12.9	76.3	17	5.1	88.1
0.71-0.80	29	5.5	89.3	13	6.7	83.0	16	4.8	92.9
0.81-0.90	12	2.3	91.6	8	4.1	87.1	4	1.2	94.1
0.91-1.00	44	8.4	100.0	25	12.9	100.0	19	5.9	100.0
Total	525	100.0		194	100.0		331	100.0	

Table 4 shows that the TE scores had a wide distribution ranging between 0.07 and 1.0. Such a wide variation in efficiency among smallholder tea farmers was also reported in the studies by Kiprono (2013) and Nguyen-van and To-the (2014) who reported a distribution ranging from 0.01 to 0.74 for smallholder tea farmers in Kenya, and 0.05 to 0.95 among smallholder tea farmers in northern Vietnam, respectively. The distribution is however inconsistent with Hong and Yabe (2015) who reported a distribution ranging from 0.62 to 0.97 for Vietnamese smallholder tea farmers. The frequency distribution of the TE scores across the sample indicates that smallholder tea farmers in the study area were comparatively less efficient with majority (66.3 percent) having relatively low TE scores (< 0.5), while only 8.4 percent had scores of more than 0.9. The farmers from Nyamira County were proportionately less efficient than their counterparts from Bomet County because the proportion of farmers whose TE scores were above 0.5 was 51 percent for Bomet compared to only 24 percent in Nyamira County.

Under VRS assumptions which the study adopted in the estimation of efficiency scores, TE can be decomposed into two mutually exclusive and non-additive components; Pure TE and scale efficiency (SE). The first component reflects the managerial performance of the farm in organizing inputs in the production process. The latter component expresses whether a farm is operating on an optimal scale and provides a measure of the farm's ability to choose the optimal size. Such decomposition is useful in providing insights about the sources of inefficiency since inappropriate size (too large or too small) may also be a cause of inefficiency in production. The comparative analysis of the average TE and SE scores for the smallholder farmers in the two counties is presented in table 5.

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Table 5: The Mean TE scores for Bomet and Nyamira County

	Bomet (n =194) Mean	Nyamira (n=331) Mean	Difference		sample (n=525)	
			Difference	t statistic	Mean	Std Dev
Mean TE	0.55	0.41	0.14***	7.03	0.46	0.24
Mean SE	0.82	0.59	0.23 ***	9.38	0.67	0.28

The asterisks (***) denotes statistically significant difference at 1% level

As shown in table 5, the mean TE score obtained in the overall sample was 0.46 showing that smallholder tea farmers in the study areas were technically inefficient and are less successful in employing the production technology of the best practice farmers. Although the average TE score estimate in this study is higher compared to the 0.15 from Kiprono (2013) for smallholder tea farmers in Kenya, the result still indicates that there exists enormous opportunities for efficiency gains in tea production in the two counties. This is because, the average efficiency score of 0.46 means that by adopting the production practices of the best practice farmers, smallholder tea farmers can achieve their current tea production levels using only 46 percent of the resources currently in use under tea production. There is therefore a considerable potential in the smallholder tea sector to improve the wellbeing of tea farmers through improvement in TE.

The results further show statistically significant difference in the means of the TE and SE scores between Bomet and Nyamira with smallholder tea farmers from Bomet performing significantly better than their counterparts from Nyamira County. The better performance in TE by smallholder tea farmers in Bomet County may be attributed to the fact that the county had better adoption levels of clonal tea varieties and relatively younger tea bushes. The other probable factors would be the more intensive use of fertilizer and better access to credit and FFS extension as revealed in the summary statistics on the sample data. The difference in efficiency levels suggests that although the tea growing areas appear to have relative similarities in agro-ecological conditions, there are location specific heterogeneities that influence the attainment of efficiency in smallholder tea production. Such heterogeneities need to be considered in policy formulations targeting improved efficiency in the tea sector.

The SE scores provide empirical evidence that smallholder tea production is not scale neutral and the contribution of scale is an important source of efficiency variation in tea production. The source of scale inefficiency was analysed in terms of whether a farm was characterized by increasing or decreasing returns to scale. Understanding of returns to scale is important in indicating whether any efficiency gains can be obtained by adjusting the size or scale of operation of a farm (Tolga *et. al.,* 2009). For instance, farms experiencing increasing returns to scale can benefit by becoming larger or similarly farms at the optimal scale can suffer efficiency losses if the scale of production is adjusted. Table 6 shows the distribution of the DEA model results on return to scale among the sampled tea farms.

Table 6: The Distribution of Returns to Scale from the DEA Model

Returns to scale	Frequency	Percent	Cumulative
Decreasing (DRS)	44	8.38	8.38
Increasing (IRS)	470	89.52	97.9
Optimal scale (OS)	11	2.1	100.0
Total	**525**	**100**	**100.0**

The results revealed that only 2.1 percent of the farmers were operating at optimal scale. Majority of the farms (89.5 percent) were characterized by increasing returns to scale while 8.3 percent of the farms exhibited decreasing returns to scale. The fact that majority of the smallholder tea farms in the study area are not operating at or near to their optimal scales suggests that there are scale advantages in tea production which can be harnessed by increasing the scale of operation of the smallholders.

c) The Determinants of Technical Efficiency

To analyse the determinants of TE in smallholder tea production, the TE scores obtained from DEA were regressed on various explanatory variables hypothesised to be correlated with TE. The marginal effects from the estimated model are presented in table 7. Various model diagnostic tests were conducted on the estimated model and the results presented in table 8 indicate that the selected covariates provided good estimate of the estimated specification.

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Table 7: The Marginal Effects from the Fractional Regression Model

Variable	Dependent Variable: TE Score		Z value	P value
	Coefficient	Std. error		
Farm size	-0.165***	0.031	-5.27	0.000
Square of farm size	0.021***	0.006	3.35	0.001
County dummy	0.157***	0.021	7.37	0.000
Variety of tea	0.011	0.019	0.58	0.561
Age of farm	-0.006**	0.003	-2.23	0.026
square of age of farm	0.000	0.000	1.76	0.078
Gender of household head	-0.015	0.028	-0.55	0.585
Education (primary)	0.080**	0.035	2.29	0.022
Education (secondary)	0.074**	0.034	2.17	0.030
Education (college)	0.077*	0.040	1.91	0.057
Extension (FFS)	0.053***	0.019	2.79	0.005
Distance to market	-0.002	0.004	-0.53	0.598
Labour structure	0.046*	0.024	1.91	0.055
Market channel	0.074***	0.021	-3.58	0.000

*The asterisks denotes significance (*** at 1%, ** at 5% and * at 10 %) and the marginal effects for dummy variables refer to the discrete change from 0 to 1*

Table 8: The model diagnostic tests results

Test	Test	Ratio/value	P value
Wald test : Chi ^{2} (14 df)	Goodness of fit	200.49	0.000
Link test for model specification:			
Hat coefficient	Specification	1.569	0.000
Hat^2 coefficient		-0.244	0.399
LM test : Chi ^{2} (14 df)	Heteroskedasticity	8.63	0.656

From table 8, the p-value of the Wald test statistic was less than 0.01indicating that explanatory variables are jointly statistically significant in influencing efficiency in the smallholder farms in the sample. It was therefore concluded that the model was correctly specified.

The results in table 7 show that farm size, age of the farm, level of education attained by the household head, access to extension services, the labour structure and use of alternative marketing channels other than KTDA have significant influence on the level of efficiency attained by smallholder tea producers in the study area. The coefficients for variety of tea planted, gender of household head, and distance to the nearest market were statistically insignificant. The latter suggests that variations in efficiency scores across the sampled farms cannot be attributed to observed differences in tea varieties planted, gender of household head or distance travelled to markets.

The results of the regression confirm significant difference in efficiency across the different counties because of the positive and statistically significant coefficient of the county dummy, which was included to capture the effects due to location specific or regional heterogeneities. The results indicated that on average smallholder tea farmers in Bomet were technically more efficient than those in Nyamira County as had been reported in the data summaries in table 5. Findings of Kavoi *et al.* (2001) and Kiprono (2013) had also indicated regional heterogeneities in smallholder tea productivity between farms on the west and east of the Rift Valley.

The coefficient for farm size was negative while that of its quadratic term which was introduced to examine whether the negative effects of farm size on TE would persist at all levels of farm size was positive and also statistically significant. The finding indicate that the effect of farm size on efficiency is non-linear with TE first falling and then rising with increase in farm size. This result is at variance with the inverse productivity relationship that is reported among various agricultural enterprises in various countries (Rios and Shively, 2005) but is consistent with the tea farm consolidation and enterprise diversification programs envisaged in the proposed National Tea Policy (Republic of Kenya, 2014a).

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The age of the tea farm was considered in the study guided by the fact that peak yields for tea are obtained between ages of 25 to 40 years after planting, followed by a decline to a level where the tea gardens may become moribund (Kamau, 2008). The coefficient for the variable was negative with a magnitude indicating that increase in the age of the tea farm by one year about the average age of 27 in the sample, would lead to a reduction in TE by 0.006. However, the coefficient of the square of age of the firm was statistically insignificant indicating lack of empirical evidence for a non-linear relationship with efficiency achievements among the sampled smallholder tea producers. The results are consistent with experimental studies that have shown that younger tea plantations are generally associated with higher productivity in most tea growing regions in the world (Bore, 1996) and are also in conformity with tea industry's assertions that aging tea gardens were causing stagnation in tea productivity (Republic of Kenya, 2014a). To reverse the decline in yields due to aging of tea bushes, other countries such as Sri Lanka, India and Malawi are implementing tea replanting programs for their smallholder farmers.

On the level of education attained by the household head, the results show significant differences in efficiency levels of farm household heads with tertiary, secondary or primary levels of education when compared to those with university education. Smallholder farms whose household heads have lower than university education had higher levels of TE than farm households headed by individuals with university education. The result is inconsistent with the expectation that education should improve access to information and understanding on the importance of proper farming practices. However, a plausible explanation could be related to the fact that more educated farmers have a higher opportunity cost of labour as they can earn higher returns outside farming (Yoshiko, 2010). This leads to differential allocation of time to tea farming activities where the farmers with university education although deriving some incomes from tea farming, could be allocating less time to tea production activities.

The positive coefficient for the FFS extension suggests that tea farms household that had participated in the FFS program were more efficient than the non-participating ones. This is similar to the results in Onduru *et al.* (2012) who found that participation in FFS had a positive and significant influence on tea yields in selected tea growing regions in Kenya. The FFS is a new approach to extension which was adopted by the tea sector to address the weaknesses of the conventional training and visit (T&V) approaches (Mose *et. al.,* 2016). The attractiveness of FFS is associated with its use of participatory adult leaning approaches and emphasis on stronger linkages between research, extension and farmer experimentation (Friis-Hansen, 2004).

For labour structure, the coefficient was positive implying that an increase in the share of family labour applied in tea production is associated with higher levels of efficiency. Ogada *et al.* (2014) found a similar outcome on food crops production in Kenya where households that utilized hired labour had lower TE scores than households that used family labour. Regarding the marketing of green leaf, the coefficient for market channel was positive with a value of 0.074. This means that on average, the TE of farm households that had participated in the alternative tea market channels was higher compared to those households that had not participated.

Although the adoption of high yielding crop cultivars is thought to be one of the major sources of productivity growth in agriculture, the study found a statistically insignificant influence. The results suggest that the variety of tea planted was not an important source of difference in the TE scores of the sampled households. Kiprono (2013) also found that tea variety was not an important source of efficiency variation in tea production in Kenya. The finding may be due to the possibility that gains from the improved varieties are countervailed by the fact that traditional varieties are more adaptable to climatic variability and adverse growth conditions. The traditional seedling varieties have the ability to develop a vertically descending tap root unlike the clonal varieties which have a tendency to develop a spreading root system within the fertile and upper layers of the soil (Wickramaratne, 1981).

The coefficient for gender of the household head was insignificant implying that the TE of farm households headed by females was not statistically different from the TE of the farm households headed by males. Although the finding is in contrast with Hong and Yabe (2015) who found that male headed households had higher levels of TE than the female headed households, it is not a strange occurrence. Quisumbing (1996) in a survey on differences in TE between male and female farmers in agricultural production across various studies found that six in seven studies had insignificant dummies for gender of the household head. Chirwa and Kydd, (2006) also found no statistical evidence of gender differences in tea productivity in Malawi.

The distance to markets was included as an indicator of market related transaction costs since an increase in the distance to markets can act as an economic disincentive to the farmers. The estimated coefficient for distance to nearest market was not statistically significant. This might be explained by the recent improvements in road infrastructure in the country and the emergence of motorbikes as a popular mode of transport in rural areas. The improved access to market as a result of these developments would have diminished the influence of distance to markets as a variable explaining TE in tea farming.

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IV. Conclusions and Policy Implications

This study has revealed that smallholder tea farmers are technically inefficient with an estimated TE efficiency score of 0.46 which indicates an opportunity for many farmers to enhance their technical efficiency and productivity. Analysis of the determinants of efficiency scores provide information that TE in smallholder tea production can be improved through policies that promote adoption of labour saving technologies, consolidation of management in the small tea farms in order to benefit from the scale advantages, expansion of the FFS extension program and tea replanting to replace the aging or moribund tea gardens. The policy formulation in the tea sector should also accounts for the county specific heterogeneities in the different tea growing counties. This would require measures that foster adequate participation of all the key stakeholders at the county level during the policy formulation process.

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Unless specified in the notification, the Editorial Board's decision on publication of the paper is final and cannot be appealed before making the major change in the manuscript.

Acknowledgments

Contributors to the research other than authors credited should be mentioned in Acknowledgments. The source of funding for the research can be included. Suppliers of resources may be mentioned along with their addresses.

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Preparing your Manuscript

Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.

Manuscript Style Instruction (Optional)

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11'", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
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.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.



Format Structure

It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

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Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Keywords

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

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Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, “What words would a source have to include to be truly valuable in a research paper?” Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

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Numerical methods used should be transparent and, where appropriate, supported by references.

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Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

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Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

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Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

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Tips for Writing a Good Quality Science Frontier Research Paper

Techniques for writing a good quality Science Frontier Research paper:

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2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

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7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

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11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

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Mistakes to avoid:

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- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.
- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

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Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- 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.
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- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
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Approach:

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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.

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- 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.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

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

If you desire, you may place your figures and tables properly within the text of your results section.

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If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

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Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

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- 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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Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
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

INDEX

A

Acaricides · 10

B

Botanicae · 42
Bouyoucous · 25, 33

C

Chaenomeles · 3, 5, 6

D

Decoteau · 23, 33
Demodexcanis · 8

E

Erythematosus · 10

I

Insectpests · 37
Isoquant · 62, 63
Ivermectin · 8, 9, 12

L

Leykoantotsianins · 5

M

Malgorzata · 4, 7
Marschner · 28, 34
Milbemycin · 9

R

Refractometer · 4

S

Steriobinocular · 15

T

Troyan · 3, 4

W

Wickramaratne · 70, 73
Wondmeneh · 45, 56



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ISSN 9755896



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