OPEN ACCESS

African Journal of **Plant Science**

May 2018
ISSN 1996-0824
DOI: 10.5897/AJPS
www.academicjournals.org

ACADEMIC JOURNALS
expand your knowledge

ABOUT AJPS

The **African Journal of Plant Science (AJPS)** (ISSN 1996-0824) is published Monthly (one volume per year) by Academic Journals.

African Journal of Plant Science (AJPS) provides rapid publication (monthly) of articles in all areas of Plant Science and Botany. The Journal welcomes the submission of manuscripts that meet the general criteria of significance and scientific excellence. Papers will be published shortly after acceptance. All articles published in AJPS are peer-reviewed.

Contact Us

Editorial Office: ajps@academicjournals.org

Help Desk: helpdesk@academicjournals.org

Website: http://www.academicjournals.org/journal/AJPS

Submit manuscript online http://ms.academicjournals.me/

African Journal of Plant Science

Table of Content: Volume 12 Number 5, May 2018

ARTICLES

academicJournals

Vol. 12(5), pp. 98-104, May 2018
DOI: 10.5897/AJPS2017.1627
Article Number: 4C1B2A156935
ISSN 1996-0824

http://www.academicjournals.org/AJPS

African Journal of Plant Science

Full Length Research Paper

Evaluation of chemical, botanical and cultural management options of termite in Tanqua Abergelle district, Ethiopia

Atsbha Gebreslasie[1*] and Hintsa Meressa[2]

[1]Mekelle Agricultural Research Center, P. O. Box 258, Mekelle, Ethiopia.
[2]Abergelle Agricultural Research Center, P. O. Box 44, Abi-Adi, Ethiopia.

Received 26 November, 2017; Accepted 5 February, 2018

The study was carried out to evaluate the effect of botanical, chemical and cultural methods on the management of termite in seedling beds of hot pepper in Tanqua Abergelle district of Sheka Tekli during 2015-2016. The experiment comprised of treatments including Neem Leaf extract, wood ash, Dursban and control and each treatment was applied at 40 kg ha^{-1}, 10000 kg ha^{-1}, and 0.5 L ha^{-1} respectively. The experiment was designed through Randomized Complete Block Design and each treatment was replicated thrice. The treatments were applied directly on seedling beds while seeds were sown. Data was collected after six weeks of sowing pepper seeds. The numbers of healthy seedlings were significantly affected by the application of treatments. Hence, the highest number of seedlings at six weeks after sowing (1658250 seedlings ha^{-1}) and transplanting (1505490 seedlings ha^{-1}) were recorded on plots treated with dursban and neem leaf extracts respectively. Likewise, lower NUMBER of seedlings damage was recorded on beds treated with dursban (504510 seedlings ha^{-1}) and Neem leaf powder (623100 seedlings ha^{-1}) compared with untreated experimental plots. The highest net return (74020 Birr) with a marginal rate of return (42.64 Birr) was obtained with application of neem leaf extract. Thus, the application of neem leaf extract alone or interchangeably with dursban should be promoted to farmers of Tanqua Abergelle district and other location with the same environmental conditions to easily manage termite on the seedling of hot pepper.

Key words: Termite, pepper seedling, damage percentage, control method.

INTRODUCTION

Termites are social insects that belong to the Isoptera order. They are occasionally associated with severe damage to rangeland vegetation, particularly, in degraded arid and semi-arid ecosystems. Termites are destructive structural pests as well as agricultural pests found primarily in the tropical regions of the world, where they play an important ecological role in the recycling of Wood and other cellulose-based materials (Abdurahaman,

*Corresponding author. E-mail: atsbha1415@gmail.com.

1990). There are currently approximately 2,800 named termite species in 282 genera worldwide. Of the most economically important termite spp. *Macrotermes subhyalinus* (Rambur) and *Microtermes adschaggae* (Sjosted) are widely observed in the region (Abdurahman, 1990).

Currently, many regions of the world are subjected to expansions and/or invasions of subterranean termites. In some areas, including Ethiopia, termite constitutes a significant pest problem in agriculture. In general, plants exotic to the specific area and water-stressed plants are most prone to attack by termites. They are serious pests of a wide range of crops, forest trees and buildings in Western Ethiopia (Hailemichael Taye et al., 2013; Legesse et al., 2013). It is also the most economically important insect pest of many crops in Tanqua Abergelle district.

Termite infestation and damage starts while plants are standing in the field. A soil infested with termite mostly resulted in distortion of soil structures and compactions. Hence soil becomes difficult to plough, this in turn results in a reduction of productivity of crops. Termites are devastating insect pests which caused 36 to 62% reduction in yields of hot pepper and maize, respectively. Termites also cause severe devastations on the forest, and thus soil remains bare and exposed to elements of soil erosion (Abraham, 1990; Kumar and Pardeshi, 2011; Bong et al., 2012). As a result, farmers are forced to leave their farmlands (Abraham and Adane, 1995). Yield loss depends on the type of crop, the extent of stand reduction and the attack at the different growth stage of the crops by termites. Abdurahaman (1990), stated that 45% crop removal at the six-leaf resulted in 16.5% of yield loss, whereas the same reduction at the tasseling stage caused 39.9% yield loss. Addisu et al. (2014) also stated that severe infestation of termite spp. could cause up to 100% crop losses in Ethiopia.

Unlike the effect on the environment and cost, the use of some chemical insecticides are highly effective against termite (Kumar et al., 2012). Chemical spray with Dursban is highly effective in the management of wood destroying termites (Roll, 2007). The possibilities of using different control measures such as fungal insecticides, bio-insecticides and botanical method rather than chemical insecticides have been reported (Silva et al., 2012; Sujatha et al., 2012). The application of crop residue and cattle manure reported reducing the number of termites on crop fields' by 21.6 and 29.7% compared to non-treated fields (Legesse et al., 2013). There are also many plant-based botanicals that could act against termites in crop fields and vegetations. The latex and quinines of some botanicals like *Calotropis procera*, *Ipomoea fistulosa*, *Maesa lanceolata*, *Croton macrostachyus*, *Tegetes minuta*, *Datura stramonium* and *Azadirachta indica* are reportedly used for the management of termites throughout the world (Derbalah et al., 2012; Singha et al., 2013; Upadhyay, 2013). The use of indigenous plant extracts as an alternative for insect pest control also reported (Abdullahi et al., 2011; Sathyaseelan et al., 2008). The use of leaf powders of *Azadirachta indica* and *Maesa lanceolata* were found to be effective in controlling termite on hot pepper at Bako (Sisay, et al., 2008). According to Venmalar and Nagaveni (2005), Neem extract contains toxic constituents exhibiting high toxicities against different microbes and insect pests.

Some research works had been conducted to investigate the effectiveness of biopesticides against termite. However, the assortments of best commercial products are limited and insufficient to fulfil the requirements of small-scale farmers throughout Tigray region. Hence, the study was initiated to evaluate the performance of the application of chemical, botanical, and cultural control methods with respect to plots maintained with no termite control activities to screen the best termite control strategies.

MATERIALS AND METHODS

Description of study area

The experiment was carried out during 2015/2016 production season for two years. It was undertaken at Sheka Tekli kebele of Tanqua Abergelle district where termite is the main production constraints of pepper seedlings. The study area is located at 13°14'06" N Latitude and 38°58'50"E longitudes and its average altitude are below 1500 m above sea level (Figure 1). The area is characterized as hot warm sub-moist low land (SML-4b) and the average annual rainfall ranges from 350 -700 mm with minimum and the maximum temperature is 24 and 41°C respectively.

Experimental materials and design

The experiment comprised four types of management methods including chemical, botanical treatment, the cultural method using Wood ash and termite infested checks. The treatments were arranged using a Randomized Complete Block Design (RCBD) and each treatment was replicated thrice. Twelve experimental plots including check were used. Finally, all experimental units were treated uniformly at the same time. Dursban, Neem leaf extract, and wood ash were treated at a rate of 0.5 L, 24 and 6 kg per hectare basis respectively. The spacing between plants, rows, pathway and block were 2, 15, 50 and 100 cm respectively.

Preparation and application of Neem extracts and Wood ash

Fresh leaves of Neem were collected, sun-dried for three days and ground into powder using mortar and pistol. Likewise, 12 g of Neem leaf powder was weighed and dissolved in 120 mL of water. The suspension was fermented for half a day, eventually strained and poured into a liter of water. 20 g of detergent (emulsifier) was measured and thoroughly mixed with the extract to ensure uniform distribution of active ingredients while seedling beds were treated. Seedbeds were immediately covered with a layer of soil after the extract was sprayed to reduce rapid evaporation of extracts from the bed.

On the other hand, a well-prepared 5 kg of wood ash was weighed and spread uniformly to the seedling beds. Eventually, the

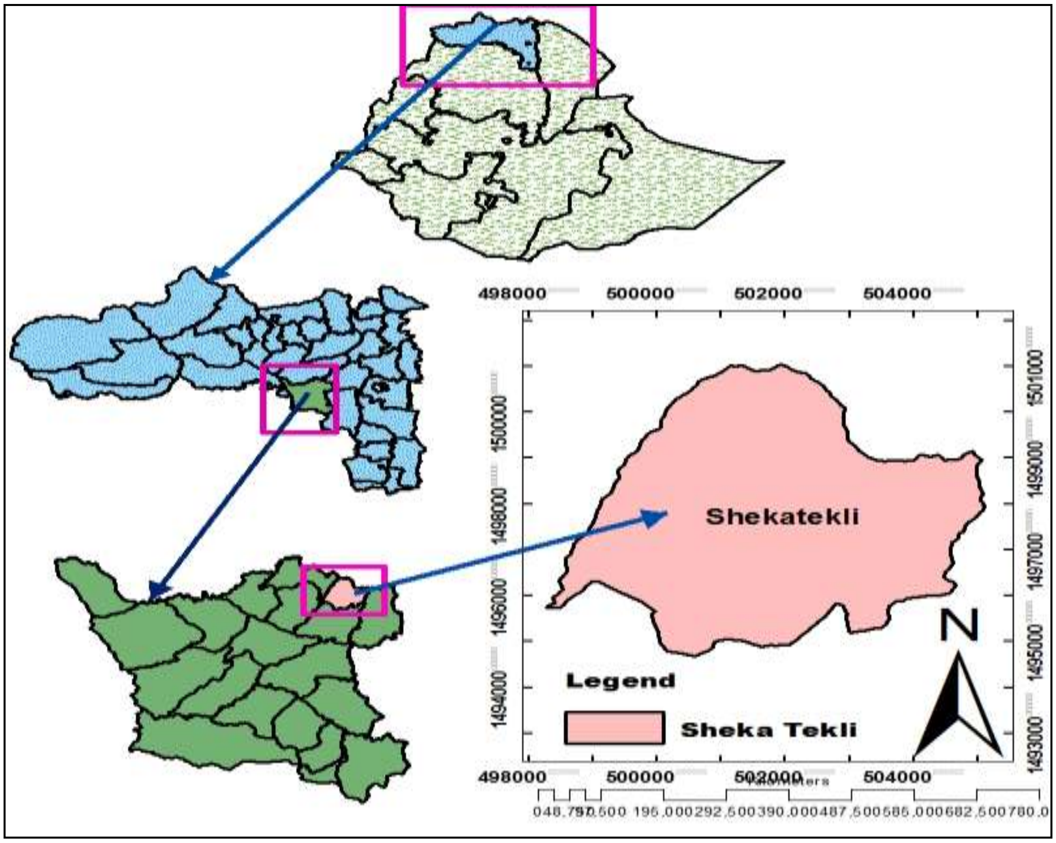

Figure 1. Geographic map of the study site location (Sheka Tekli kebele).

ashes were properly mixed with the soil ahead of sowing the seeds of hot pepper. Unlike the botanicals, the ash was spread a day ahead of sowing the seeds of the vegetable crop.

Data collection and analysis

The seedling beds were regularly monitored every seven days until seedlings were ready for transplanting. Basic data such as the number of seedlings at 75% seedling emergence, number of seedlings at 16 days after seedling emergence, seedling survival rate at 16 days after seedling emergence, number of seedlings at transplanting and number of damaged seedlings at transplanting were collected and subjected to statistical software for analysis. SAS Statistical Software Package (SAS, 2001) was employed both for analysis of variance and for determination of mean separation among differently treated seedling beds. The prevention and infestation rate (percentage) of management practices were determined based on the following formula:

$$\mathrm{PR}\ (\%) = \frac{\mathrm{DS\ UTSB} - \mathrm{DS\ TSB}}{\mathrm{DS\ UTSB}} \times 100$$

$$\mathrm{IR}\ (\%) = \frac{\mathrm{DS\ TSB}}{\mathrm{DS\ UTSB}} \times 100$$

Where, PR (%) = stands for prevention rate; DS UTSB= number of damaged seedlings on untreated seedling beds; DSTSB= Number of damaged seedlings on treated seedling beds, IR (%) = stands for infestation rate respectively.

Cost-benefit analysis

The partial budget analysis was manipulated to assess the economic feasibility of new management options of termite to be imposed on the agricultural business. It was implemented to organize data and generate information about the cost incurred and the benefits gained from various agricultural options. The marginal rate of return was used to measure the effect of investing additional capital on net returns of the newly implemented management options compared with the existed practices. It provides the value of the benefit obtained from the additional cost being incurred. The partial budget analysis was done based on the additional cost incurred to the variable and fixed costs to each of the management practices. Nevertheless, it was considered that the total costs incurred for land rent were equal to both management practices. Therefore, the impact on the additional rate of return remains constant among management options. The price of the input (cost of chemicals, botanicals, ash and the labour cost) and the products (seedling price) were determined based on the seasonal market prices at the local market. Finally, the marginal rate of return (MRR) was determined as suggested (Kelly et al., 2005) as below:

$$\mathrm{MRR} = \frac{DNI}{DIC}$$

Where, MRR = Marginal rate of return, DNI = Difference in net

Table 1. Expected number of pepper seedlings and actual number of seedlings at 16 days after emergence.

Treatments	Parameter			
	ESE ha^{-1}	ASE ha^{-1}	SSC 16 DAE ha^{-1}	SSR 16 DAE
Neem leaf extract	2,010,000	1996600^{b}	1497450^{b}	0.75^{b}
Dursban	2,010,000	1997892^{ab}	1658250^{a}	0.83^{a}
Wood ash	2,010,000	1996419^{c}	1477350^{c}	0.74^{c}
Control	2,010,000	1998176^{a}	1358760^{d}	0.68^{d}
LSD(0.05)	ns	57.7	57.7	5.77
CV (%)	5	4.2	4.2	4.2

*Treatment means where different letter stands for statistical difference among treatments using Fisher least significant difference at α = 0.05; ESE Ha-1 = Expected number of seedling emergence per hectare; ASE Ha-1 = Actual number of seedlings per hectare; SSC 16 DAE Ha-1 = seedling stand to count at 16 days after emergence per hectare.

income compared with control (untreated plots) and DIC = Difference in input cost compared with control (untreated plots).

RESULTS AND DISCUSSION

Expected and actual number of seedling at 16 days after emergence

The germination and emergence status of seedlings were relatively good while seeds were sown until few weeks after emergence. Two weeks later (16 days after emergence), a number of seedlings in some beds showed wilting symptoms due to termites and eventually some of them died due to severe infestation by termites. Despite this, there was a relative difference in the level of infestation among management practices; both termite and the damaged seedlings were observed in all beds treated with dursban, neem leaf extract, and wood ash. However, the infestation prevailed in those beds treated with wood ash and the untreated checks. Based on the result of the experiment indicated in Table 1, a statistically significant difference was observed among seedling beds treated with neem leaf extract, dursban (48%), wood ash and the untreated beds for the number of seedlings at emergence. Initially, a relatively highest number of seedlings emerged on beds treated with dursban (1997892 seedlings ha^{-1}) and on the untreated beds (1998176 seedlings ha^{-1}). In the contrary, lower number of seedlings was recorded on beds treated with wood ash and neem leaf extract (Table 1). The analysis of variance result indicated that all pepper seedling beds treated with dursban, neem leaf and wood ash had a significant number of seedling at emergence compared to the untreated nursery beds. The highest number of the seedling counts at 16 days after sowing were recorded on nursery beds treated with dursban (1658250 seedling ha^{-1}) followed by beds treated with neem leaf extract (1497450 seedling ha^{-1}). Conversely, the lowest numbers of seedlings per hectare (1358760 seedlings ha^{-1}) were recorded on untreated nursery beds (control). The current result confirmed that dursban is also highly effective in the management of termites on hot pepper seedling beds beside its effectiveness on the management of wood destroying termites (Roll, 2007). Several other authors also stated that botanicals like *Calotropis procera*, *Ipomoea fistulosa*, *Maesa lanceolata*, *Croton macrostachyus*, *Tegetes minuta*, *Datura stramonium* and *Azadirachta indica* were reportedly used for the management of termites throughout the world (Derbalah et al., 2012; Singha et al., 2013; Upadhyay, 2013).

Number of healthy and damaged seedling during transplanting

Statistically, a significant difference was observed among seedling beds treated with dursban (48%), neem leaf extract, wood ash and the untreated beds (termite-infested beds). Likewise, the highest number of seedlings count at transplanting were recorded at seedling beds treated with Dursban (1505490 seedling ha^{-1}) followed by neem leaf extract (1487400 seedling ha^{-1}) while the lowest number of seedling stands were recorded on untreated beds (1181880 seedling ha^{-1}). The lowest numbers of seedlings having termite damage symptoms were recorded on beds treated with dursban (504510 seedling ha^{-1}) than those beds treated with wood ash (709530 seedling ha^{-1}) and the untreated seedling beds (829125 seedling ha^{-1}) respectively (Table 2). In contrast, the highest rates of seedling death during transplanting seedling were recorded on untreated beds (control). The independent uses of wood ash on pepper seedling beds remain ineffective compared to the treatment of seedling beds with dursban and neem leaf extract as management option of sub-terrain termites. Hence, the result is in line with the finding of Abdurahaman (1990) who also stated that the use of some cultural control methods such as mound distraction, removal of the queen, flooding water into the mound, use of wood ash and hot pepper

Table 2. Average number of healthy and damaged seedlings during transplanting.

Treatments	Parameter	
	Number of healthy seedlings at transplanting (45 DAE)	Number of damaged seedlings at transplanting (seedling ha^{-1})
Neem leaf extract	1487400[ab]	623100[ab]
Dursban48%EC	1505490[a]	504510[a]
Wood ash	1300470[c]	709530[c]
Control	1181880[d]	829125[d]
LSD(0.05)	61.8	61.8
CV (%)	5.11	9.28

*Treatment means where different letter stands for statistical difference among treatment means using Fisher's least significant difference at α = 0.05 probability level; DAE= stands for days after emergence.

Table 3. Prevention and infestation rate of termite on pepper seedlings expressed in percent.

Treatments	Parameter	
	Prevention rate (%)	Infestation rate (%)
Neem leaf extract	25	75
Dursban48%EC	39	61
Wood ash	14	85
Control	0	100

independently, are not effective. However, Sisay et al. (2008) stated that the use of leaf powders of *A. indica* was effective in the management of termite on the hot pepper.

Prevention and infestation rate of termite on hot pepper

There was a difference in prevention and infestation rates of termite among differently treated seedling beds. Chemical spray with dursban was effective in the management of termite followed by seedling bed treatment with neem leaf extract. It had been observed that chemical treatment of seedling beds with dursban was relatively effective at preventing early deaths of pepper seedlings (39%) by termite compared to wood ash and the untreated seedling beds. Besides, the lowest rate of termite infestation was observed on beds that were treated with dursban 48% (61%) and Neem leaf extracts (75%). The treatment of seedling beds with neem leaf extract was reduced the expected seedling damage due to termite by 25%. Conversely, the lowest prevention and the higher rate of termite infestation were recorded on beds treated with wood ash and untreated beds (Table 3).

The trend of the graph also entailed that the prevention rate of termite management methods differed among neem leaf extract, dursban (48%) and wood ash with reference to the untreated beds (control). Though dursban and neem leaf extract were not the same at prevention of termite, the graph had shown an increasing trend of protection from seedling bed treatment with neem leaf extract to dursban (48%). Relatively, there was a decreasing trend in preventing rates of termite with independent use of wood Ash. Unlike neem leaf extract and dursban, the infestation rate of termite increased with the use of wood ashes and infested checks (Figure 2).

Cost-benefit analysis of management practices

The cost-benefit analysis result provides the necessary information about the economic feasibility of management practices and to reach possible recommendations. It was noticed that any management options with net benefits less than or equal to those options with lower cost were considered to be inferior (dominated). Accordingly, the highest net benefit was gained on management options with additional expenditures of 450 Birr. However, the expenditure that appeared to be more attractive was determined based on the result of the marginal rate of return. Thus, the maximum net benefit of 74020 Ethiopian Birr with the average marginal rate of return (42.64 Birr) was generated from application of neem leaf extract compared to the use of chemical spray with dursban (35 Birr). That means for every one Birr additional investment on using neem leaf extract for management of termite will result in 42.64 and 74020 Birr of return and net benefits

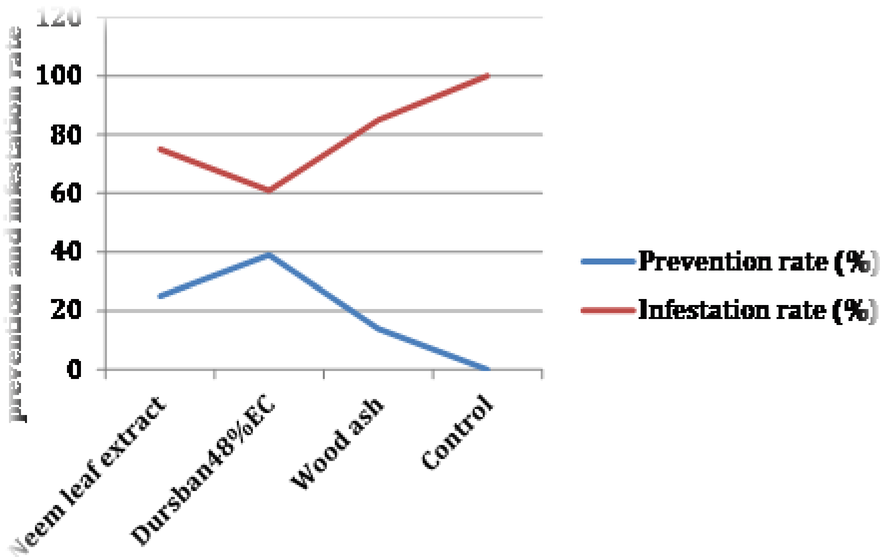

Figure 2. The graphical illustration of the effect of botanical, chemical and cultural management practices on termite infestation and prevention rate.

Table 4. Costs benefit analysis of applying Neem leaf extract, Durban and Wood ash treatments on the management of termites.

Treatments	Cost-benefit data				
	Seedling ha^{-1}	**Price per seedling (cents)**	**MVP (E Birr)**	**TVC cost (Birr ha^{-1})**	
Neem leaf extract	1487400	5	74370	350	
Dursban48%EC	1505490	5	75274.5	450	
Wood ash	1300470	5	65023.5	500	
Control	1181880	5	59094	0	
	MC (Birr ha^{-1})	**NB (Birr ha^{-1})**	**MB (Birr ha^{-1})**	**MRR (%)**	**Dominated**
Neem leaf extract	350	74020	14926	4264	No
Dursban48%EC	450	74824.5	15730.5	3500	No
Wood ash	500	64523.5	5429.5	1086	Yes
Control	0	59094	0	0	

MC = marginal cost in Ethiopian birr; **MB =** Marginal benefit in Ethiopian birr; **MRR =** marginal rate of return. **MVP =** marginal value product in Ethiopian birr; **TVC =** total variable cost in Ethiopian Birr.

gain, respectively. This implied that the use of neem leaf extract to manage termite was economically feasible compared to additional investment in chemical spray using dursban. For every one-birr investment in application of Dursban, there was 35 Birr rate of return plus 15730.5 Birr net benefit (Table 4). In general, the higher net benefit was gained through application of neem leaf extract with minimum input difference. This indicated that farmers would be profitable if they apply Neem leaf extract as management options of termite on seedling beds of hot pepper throughout Tanqua Abergelle district and in other locations where termite is a serious constraint in production pepper.

CONCLUSION AND RECOMMENDATION

The result of the experiment indicated that dursban was effective in the management of termite in seedling beds of hot pepper followed by the use neem leaf extract compared to the treatment of beds with wood ash. The highest number healthy seedlings at 16 days after emergence and during transplanting were recorded in seedling beds treated with dursban followed by neem leaf extract treatment. Furthermore, the highest rate of prevention and the lower rate of termite infestation were also seen at beds treated with dursban with the exception of neem leaf extract. In contrast, the highest rate of return was generated with application of neem leaf extract followed by spraying of dursban. Therefore, the applications of neem leaf extract and dursban on seedlings beds of hot pepper are economically feasible, effective and advisable to farmers of Sheka Tekli and other locations with similar conditions to manage termite and maximize production of hot pepper.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENT

We are grateful to the Abergele Agricultural Research Center for the financial and materials supports for this study. In addition, we extend our gratitude to the Crop Research Directorate of Tigray Agricultural Research Institute for the constructive comment during the technical review and during the execution of the experiment.

REFERENCES

Abdullahi N, Majeed Q, Oyeyi TI (2011). Studies on the efficacy of *Vitallaria paradoxa* seed oil on the oviposition, hatchability of eggs and emergence of *Callasobruchus maculates* (F.) (Coleoptera: Bruchidae) on treated cowpea seed. J. Entomol. 8:391-397.

Abdurahaman A (1990). Foraging activity and control of termite in Western Ethiopia. Ph.D. Thesis, University of London, Department of Pure and Applied Biology, Imperial College of Science, Technology and Medicine. SilWood Park Ascot.

Abraham T (1990).Termites: Problems and possible methods of their control in agriculture with reference to the Ethiopian condition. Proceeding of the 10th Annual meeting of the Ethiopian Entomologists, February 7-9, 1990, Norway Zurich, Switzerland. pp. 50-74.

Abraham T, Adane K (1995).The effect of seed dressing with Aldrin on termite in Maize western Ethiopia. Proceedings of the 2nd Crop Protection Society of Ethiopia, April 26-27, 1995, Addis Ababa, Ethiopia. P 23.

Addisu S, Mohamed D, Waktole S (2014). Efficacy of Botanical Extracts against Termites, *Macrotermes* spp., (Isoptera: Termitidae) under laboratory conditions. Int. J. Agric. Res. 9(2):60-73.

Bong CFJ, King PJH, Ong KH, Mahadi NM (2012). Termite assemblages in oil palm plantation in Sarawak, Malaysia. J. Entomol. 9:68-78.

Derbalah AS, Hamza AM, Gazzy AA (2012). Efficacy and safety of some plant extract as alternatives for *Sitophilus oryzae* control in rice grains. J. Entomol. 9:57-67.

Hailemichael T, Kees S, Hirpha L, Dereje F, Geleta N, Peden D (2013). Uptake of integrated termite management for the rehabilitation of degraded land in East Africa: A research into use baseline study in Diga, Ethiopia. Nile BDC Technical Report 6. Nairobi, Kenya: ILRI.

Kelly V, Jayne T, Crawford E (2005). Farmers Demand for Fertilizer in Sub-Saharan Africa. Department of Agricultural Economics Michigan State University East Lansing, MI 48824-1039.

Kumar D, Pardeshi M (2011). Biodiversity of termites in agro-ecosystem and relation between their niche breadth and pest status. J. Entomol. 8:250-258.

Kumar R, Nitharwal M, Chauhan R, Pal V, Kranthi KR (2012). Evaluation of eco-friendly control methods for management of mealybug, *Phenacoccus solenopsis* Tinsley in *cotton.* J. Entomol. 9:32-40.

Legesse H, Taye H, Geleta N, Swaans K, Fikadu D, Zziwa E, Peden D (2013). Integrated termite management in degraded crop land in Diga district, Ethiopia. In. Wolde, M. (ed). 2013, Rainwater management for resilient livelihoods in Ethiopia: Proceedings of the Nile Basin Development Challenge Science Meeting, Addis Ababa, 9–10 July 2013. NBDC Technical Report 5. Nairobi, Kenya: ILRI. Retrieved from http://hdl.handle.net/10568/34252.

Roll D (2007). Management of Wood-destroying Pests. In. Carolyn J. Randall (Ed.) Ohio. pp. 8-73.

SAS (2001). Statistical Analysis System Software. Ver. 8.2, SAS Institute Inc., Cary, NC.

Sathyaseelan V, Baskaran V, Mohan S (2008). Efficacy of some indigenous pesticidal plants against pulse beetle, *Callosobruchus chinensis* (L.) on the green gram. J. Entomol. 5:128-132.

Silva LB, Xavier ZF, Silva CB, Faccenda O, Candido ACS, Peres MTLP (2012). Insecticidal Effects of *Croton urucurana* Extracts and Crude Resin on *Dysdercus maurus* (Hemiptera: Pyrrocoridae). J. Entomol. 9:98-106.

Singha D, Singha B, Dutta BK (2013). Potential of some plant extracts to control termite pest of tea (*Camellia sinensis* L. (O) Kuntze) plantations of Barak Valley, Assam, India. Int. J. Tea Sci. 8:3-9.

Sisay A, Ibrahim A, Tefera T (2008). Management of Termite (*Microtermes adschaggae*) on Hot Pepper Using Powdered Leaves and Seeds of Some Plant Species at Bako, Western Ethiopia. East Afr. J. Sci. 2:41-44.

Sujatha S, Vidya LS, Sumi GS (2012). Prey-predator interaction and info-chemical behaviour of *Rhynocorisfuscipes* (fab.) on three agricultural pests (Heteroptera: Reduviidae). J. Entomol. 9:130-136.

Upadhyay RK (2013). Effects of plant latex based anti-termite formulations on Indian white termite *Odontotermes obesus* (Isoptera: Odontotermitidae) in sub-tropical high infestation areas. Open J. Anim. Sci. 3:281-294.

Venmalar D, Nagaveni HC (2005). Evaluation of copperised cashew nut shell liquid and Neem oil as Wood preservatives. Institute of Wood Science and Technology. Malleswaram. Bangalore, India. IRG/WP 05-05-0368368. (Accessed 22/11/2017). http://www.vertinnov.fr/fic_bdd/produits_pdf_fr_fichier/12242579720_Neem+Cashew_wood_preservative.pdf.

academicJournals

Vol. 12(5), pp. 105-113, May 2018
DOI: 10.5897/AJPS2018.1655
Article Number: 31FC1D856937
ISSN 1996-0824

http://www.academicjournals.org/AJPS

African Journal of Plant Science

Full Length Research Paper

Response of onion *(Allium cepa l.)* to deficit irrigation under different furrow irrigation water management techniques in Raya Valley, Northern Ethiopia

Yemane Mebrahtu[1*], Abraham Woldemichael [2] and Solomon Habtu[3]

[1]Ethiopian Institute of Agricultural Research (EIAR), Mehoni Agricultural Research Centre, Ethiopia.
[2]School of Bio-Systems and Environmental Engineering, Institute of Technology, Hawassa University, Hawassa, Ethiopia.
[3]Department of Land Resources and Environmental Protection (LARMP), Faculty of Agriculture, Mekelle University, Mekelle, Ethiopia.

Received 28 March, 2018; Accepted 23 April, 2018

Scarcity of water is the most severe constraint for development of agriculture in arid and semi-arid areas. Under this condition, the need to use the available water economically and efficiently is unquestionable. Based on the actual crop need, irrigation management has to be improved so that the water supply to the crop can be reduced while still achieving high yield. A field experiment was carried out at Mehoni Agricultural Research Center, Raya Valley of Ethiopia, during 2016/17 season with objectives of determining the effect of deficit irrigation on Onion yield component and crop water productivity and the effect of Conventional, Alternate and Fixed furrow irrigation on yield and crop water productivity of onion. The treatment were five deficit irrigation levels (40, 55, 70, 85 and 100% ETc), and three furrow irrigation techniques (conventional, alternate and fixed furrow) were laid out in a random complete block design (RCBD) with three replications. The highest bulb yield was obtained at 100% ETc with conventional furrow method. In terms of irrigation and water use efficiency, 40% ETc deficit irrigation level application gave the highest irrigation water use efficiency and crop water use efficiency which was significantly superior to all other treatment. Among the irrigation water application methods, the highest water use efficiency was obtained with alternate furrow application method. On the other hand, the minimum water use efficiency was recorded with conventional furrow method. Alternative furrow irrigation (AFI) gave the highest crop water use efficiency and irrigation water use efficiency whereas conventional furrow irrigation (CFI) recorded the lowest. Better crop water use efficiency and irrigation water use efficiency were obtained in the AFI and fixed furrow irrigation (FFI), while the applied water in AFI was reduced by 50% of the CFI. Therefore, it can be concluded that increased water saving and associated water productivity can be achieved without significant reduction of yield in AFI with 100% ETc of irrigation level. AFI system appears to be a promising alternative.

Key words: Alternate furrow, conventional furrow, deficit irrigation, fixed furrow, onion.

INTRODUCTION

Irrigated agriculture is the primary user of diverted water globally, reaching a proportion that exceeds 70 to 80% of the total in the arid and semi-arid zones. It is therefore not surprising that irrigated agriculture is perceived in those areas as the primary source of water, especially in emergency drought situations.

Currently, irrigated agriculture is caught between two perceptions that are contradictory; some perceive that agriculture is highly inefficient by growing 'water-guzzling crops' (Postel et al., 1996), while others emphasize that irrigation is essential for the production of sufficient food in the future, given the anticipated increases in food demand due to world population growth and changes in diets (Dyson, 1999). Globally, food production from irrigation represents more than 40% of the total and uses only about 17% of the land area devoted to food production (Fereres and Connor, 2004).

Ethiopia is the second most populous country in sub-Saharan Africa and third on the continent with a population of about 100 million. Agriculture is the main stay of 80% of the Ethiopian people. Agriculture also accounts for 40% of the gross domestic product (GDP) of Ethiopia (IWMI, 2010).

However, most Ethiopian farmers depend on low productivity rain-fed small holder agriculture, even though rainfall is very erratic, and drought occurs very frequently. In Ethiopia, almost all food crops come from rain-fed agriculture with the irrigation sub sector accounting for only about 3% (FAO, 2005). This indicates that the water potential of the country is untouched, developing and utilizing efficiently this natural resource will rise the country to be food self sufficient within a short period of time.

Furrow irrigation water application system is the most popular surface irrigation, as it requires a smaller initial investment compared to other types of irrigation water application systems. This type of irrigation method is the most widely used in Ethiopia in almost all large and small irrigation schemes (FAO, 2002). It usually causes excessive deep percolation at the upper part of the furrow, insufficient irrigation at the lower part and considerable runoff, resulting in low application efficiencies and distribution uniformities. Therefore, proper furrow irrigation practices have to be devised to minimize water application and irrigation costs and to save water at the same time maintaining higher crop yields.

Therefore, these field experiments were conducted to determine the effect of alternate, conventional and fixed furrow irrigation techniques on onion yield and crop water productivity and to determine the effect of deficit irrigation on onion yield and crop water productivity. Of these, the crop which was selected for this experiment was onion which is wildly grown in the study area. Because onion was a cash crop in the study area.

The objective of the study was to determine the effect of alternate, conventional and fixed furrow irrigation techniques on onion yield and crop water productivity, and to determine the effect of deficit irrigation on onion yield and crop water productivity.

MATERIALS AND METHODS

Description of the experimental site

This study was conducted at the research station of Mehoni Agricultural Research Centre (MehARC) in the Raya Valley, Northern Ethiopia, located 668 Km from the capital Addis Ababa and about 120 Km south of Mekelle, the capital city of Tigray regional state. Geographically, the experimental site is located at 12° 51'50'' North Latitude and 39° 68'08'' East Longitude with an altitude of 1578 m.a.s.l. The site receives a mean annual rainfall of 300 mm with an average minimum and maximum temperature of 18 and 32°C, respectively. The soil textural class of the experimental area is clay with pH of 7.1 to 8.1(MehARC, 2015).

Climatic characteristics

The average climatic data (Maximum and minimum temperature, relative humidity, wind speed, and sun shine hours) on monthly basis of the study area were collected from the near meteorological station. The potential evapotranspiration ETo was estimated using CROPWAT software version 8 (Tables 1 and 2).

Experimental treatments

The experiment included three furrow irrigation systems, that is, CFI (Conventional furrow irrigation), AFI (Alternate furrow irrigation) and FFI (Fixed furrow irrigation) and four deficit irrigation levels, viz., 40ETc, 55ETc ,70ETc, 85ETc and a control irrigation of 100%ETc making a total of fifteen treatments. The treatment combination was given in Table 3. Control irrigation implies the amount of irrigation water applied in accordance with the computed crop water requirement with the aid of CROPWAT program. The treatments were replicated three times resulting in a total of 45 plots. Hence, the design was factorial experiment in randomized complete block (RCBD) design.

Statistical analysis

The collected data were analyzed using SAS 9.1 statistical software Mean separation was carried out using least significance difference (LSD) test at 5% probability level.

RESULTS AND DISCUSSION

Onion water and irrigation demand

The reference evapotraspiration (ETo) value of the site ranged between 3.9 mm/day in January to 4.8 mm/day

*Corresponding author. E-mail: yemanemebrahtu653@yahoo.com.

Table 1. Long term monthly average climatic data of the experimental area.

Month	T_{min}	T_{max}	RH	Wind	Sun	Rad	ETo
	°C	°C	Percentage (%)	km/hr	Hours	MJ/m²/day	Mm/day
January	11.5	27.2	73	69	7.9	18.4	3.33
February	12.8	27.1	70	86	9.4	22.0	4.02
March	13.5	29.5	68	86	8.7	22.4	4.44
April	13.8	29.7	67	95	8.7	22.9	4.65
May	15.3	32.5	58	52	9.1	23.3	4.69
June	15.8	35.0	60	43	8.6	22.2	4.70
July	15.6	31.5	90	52	6.5	19.1	4.04
August	15.0	29.7	95	43	6.5	19.3	3.89
September	14.3	30.8	74	52	6.6	19.2	3.96
October	13.1	29.8	69	86	9.2	22.0	4.36
November	12.1	28.6	67	69	9.0	20.1	3.77
December	11.3	27.1	69	69	8.8	19.0	3.40

Table 2. Physical characteristics of soil at the experimental site.

Soil texture	Bulk density (g/cm^3)	Field capacity (%)	Permanent wilting point (%)	Total water holding capacity (mm)
Clay	1.1	45.47	28.47	170.02

Table 3. Treatment used in the experiment.

Irrigation level	Furrow irrigation techniques		
100%ET_c	AF1	FF1	CF2
85%ET_c	AF2	FF5	CF5
70%ET_c	AF3	FF3	CF1
55%ET_c	AF4	FF4	CF4
40%ET_c	AF5	FF2	CF3

Where; AF1, AF2, AF3, AF4 and AF5 means irrigated at alternate furrow with 100, 85, 70, 55 and 40%Etc irrigation level respectively; FF1, FF2, FF3, FF4 and FF5 means irrigated at fixed furrow with 100, 85, 70, 55 and 40%Etc irrigation level respectively; CF1, CF2, CF3, CF4 and CF5 means irrigated at convectional furrow with 100, 85, 70, 55 and 40%Etc irrigation level respectively.

in March, with an average of 4.3 mm/day for the whole growth period. Based on this output, the seasonal irrigation requirement was found to be 362.45 mm (Table 3). This amount was needed for full irrigation level treatments. Accordingly, the 85, 70, 55, and 40% of irrigation level with the furrow irrigation techniques of CFI were applied 308.1, 253.7, 199.4 and 145 mm, with AFI 210.8, 183.7, 156.6, 129.4 and 102.2 mm, and with FFI 210.8, 183.7, 156.6, 129.4 and 102.2 mm, respectively. This amount of seasonal ETc for AFI and FFI and the effective rainfall with 29.65 mm added showed the three furrows which does not irrigate at that time due to the rainfall. Crop water requirement (ETc) values were low at the beginning of the growing season, increased gradually to attain a maximum during March and April and subsequently decreased (Table 8). This result indicates that, the maximum amount of water was applied around bulb formation of the onion. This was also confirmed by Boyhan and Granberry (2001), that peak use of water generally occurs during the latter stages of bulb enlargement especially during periods of warm weather (Table 4).

Onion response to deficit Irrigation

Plant height

Plant height of onion was highly significantly ($P \leq 0.01$)

Table 4. Onion irrigation requirement in the study area.

Date	ETo	Crop	ETc	Total Rain	Effective rain	IRn	IRg
	mm/period	Kc	mm/period	mm/period	mm/period	mm/period	mm/period
13 Jan	23.4	0.5	11.7	-	-	11.7	16.71
19 Jan	22.62	0.5	11.31	-	-	11.31	16.16
25 Jan	24.3	0.5	12.15	-	-	12.15	17.36
31 Jan	23.7	0.5	11.85	-	-	11.85	16.93
6 Feb	25.62	0.56	14.3472	-	-	14.3472	20.50
13 Feb	27.93	0.67	18.7131	12	3.9	14.8131	21.16
20 Feb	29.96	0.78	23.3688	36.5	18.8	4.5688	6.53
27 Feb	30.38	0.92	27.9496	17.3	7	20.9496	29.93
6 Mar	30.17	1.05	31.6785	-	-	31.6785	45.26
13 Mar	34.16	1.05	35.868	-	-	35.868	51.24
20 Mar	32.34	1.05	33.957	-	-	33.957	48.51
27 Mar	31.01	1.05	32.5605	32	16	16.5605	23.66
3 April	33.11	1.05	34.7655	-	-	34.7655	49.67
10 April	32.27	1.02	32.9154	-	-	32.9154	47.02
17 April	31.08	0.94	29.2152	28	13.6	15.6152	22.31
Total	432.05		362.45	125.8	59.3	303.05	432.93

affected by the main effects of furrow irrigation techniques and irrigation level, but not significantly ($P < 0.05$) affected by the interaction effects of the treatments. Irrigation system, in its main effect, increased plant height significantly ($P < 0.01$), Conventional furrow irrigation techniques result in 43.99 cm height followed by 42.26 cm AFI and 41.62 cm on FFI system.

The irrigation levels were highly significantly different from each other in plant height at *($P \leq 0.01$)*. Significantly higher plant height of 46.68 cm was recorded for 100%ETc (full irrigation) of irrigation depth of water applied while 85, 70, and 50% irrigation water levels got 43.49 cm, 42.21 cm, and 40.99 cm plant heights respectively. 40%ETc of irrigation depth of water applied recorded the lowest plant height of 39.46 cm. Among the irrigation level between 70 and 55% there were no significances difference in plant height. Full irrigation level (100%) got 6.92 cm, which was greater than plant heights recorded in treatments that received 40%, irrigation level.

Plant height is a good indicator for determining the water stress. Sammis et al. (1988) reported that plant height could change at different level of water deficiency. Some authors emphasized that deficit irrigation shortens plant height (Otegui et al., 1995; Stone et al., 2001a; Pandey et al., 2000).

This finding is in agreement with the result of Aklilu (2009) and Takele (2009) who reported that the plant height of pepper decreased with decreased irrigation levels and also increase with the irrigation level. Wien (1997) indicated that plant height had a linear correlation with the availability of soil moisture. The present result was also in agreement with the work of Al-Moshileh (2007) who reported that with increasing soil water supply, plant growth parameters (plant height) were significantly increased.

Number of leaf per plant

Furrow irrigation techniques were significantly different from each other in number of leaf per plant. Significantly, higher number of leaf per plant was recorded at 9.21 (100%) followed by 85, 70 and 55%, irrigation level with the value of 8.89, 8.44, and 8.43 respectively. There were no significant difference between 70 and 55% of irrigation level. The lower number of leaf per plant was observed at 40% irrigation level with 7.82 leaves per plant.

The furrow irrigation techniques were significantly different from each other in number of leaf per plant. Significantly higher number of leaf per plant of 9.31 was recorded with convection furrow irrigation technique followed by 8.32 of AFI and 8.05 of FFI (Table 5). There were no significance difference between AFI and FFI of irrigation.

This result seems closely related to that of Biswas et al. (2003), who reported that onion bulbs of irrigated treatments gave highest leaves number per plant than the non irrigated one, whereas onion grown without supplemental irrigation gave lower number of leaves. This indicated that when plants respond to water stress by closing their stomata to slow down water loss by transpiration, gas exchange within the leaf is limited, consequently, photosynthesis and growth was slow down (Currah and Proctor, 1990). The obtained result was

Table 5. Effect of furrow irrigation techniques and irrigation levels on (PH, cm), number of leaves (NL) and bulb diameter (BD) of onion.

Furrow techniques	PH (cm)	NL	BD (mm)
CFI	43.99	9.31	55.00
AFI	42.26	8.32	53.17
FFI	41.62	8.05	49.30
LSD (P=0.05)	1.76	1.03	3.34
Irrigation level			
100%	46.68	9.21	57.1
85%	43.49	8.89	53.42
70%	42.21	8.43	53.4
55%	40.99	8.44	51.2
40%	39.76	7.82	47.3
LSD (P=0.05)	2.69	1.19	5.05
CV (%)	4.6	8.96	10.64

At P ≤ 0.05; LSD= least significant difference; CV = Coefficient of variation.

also in agreement with the findings of Wien (1997) who recorded that leaf number had a linear correlation with the availability of soil moisture.

Bulb diameter

The analysis of variance revealed that the interaction effect of furrow irrigation techniques and irrigation level showed no significant difference ($P < 0.05$) on bulb diameter, but furrow irrigation techniques and irrigation level indicated significant ($P \leq 0.05$) differences (Table 5).

The analysis of variance for the furrow irrigation techniques has shown that there was significant difference on bulb diameter due to irrigation systems. As shown in Table 5, the furrow technique shows that the largest and lowest bulb diameter was recorded. 55 mm and 53.17 mm were observed for CFI and FFI respectively. However, the least bulb diameter (49.3mm) was recorded for fixed furrow irrigation. .

In this study, the irrigation level and largest onion bulbs (57.1 mm diameter) were recorded for 100%ETc (full irrigation) amount of irrigation water applied. On the other hand, the smallest bulb diameter (47.3 mm) was recorded from irrigation level treated with 40% irrigation depth. Bulb diameter was not significantly different between 85, 70 and 55% irrigation level. The result might be because of the reason that high irrigation levels increased photosynthetic area of the plant (height of plants and number of leaves), which increased the amount of assimilate partitioned to the bulbs and increased bulb diameter.

This result is closely related to that of Kumar et al. (2007a) who observed that irrigation at 1.20 Ep produced higher mean bulb size, which decreased with the decrease reduction of irrigation amount. In the same way, Al-Harbi (2002) and Biswas et al. (2003) indicated that bulb diameter of onions were increased at higher levels of irrigation.

Similarly, Olalla et al. (2004) reported that plots which received the greatest volumes of water yielded harvests with higher percentages of large-size bulbs whereas water shortages led to higher percentages of small-size bulbs. This indicates that transpiration, photosynthesis and growth rates were lowered by water stress as stressed plant produces smaller sized bulbs (Table 5).

Marketable bulb yield

Furrow irrigation techniques showed significant effect in interaction with irrigation level on bulb yield ($P \leq 0.05$) (Table 6). Conventional furrow irrigation system produced 15738 kg ha^{-1} bulb yield with CFI 40% of irrigation water applied, which increased to 26802 kg ha^{-1} with CFI 100% (full irrigation). Fixed furrow irrigation techniques produced bulb yield of 14.326 tons ha^{-1} with 40% which increased to 20.865 tons ha^{-1} 100%, and alternate furrow irrigation system, on the other hand, produced bulb yield of 23.640 tons ha^{-1} with 100%, and 15.137 tons ha^{-1} with 40%.

In this study, the bulb yield response to fixed furrow irrigation and alternate furrow irrigation was higher at 100% than at 85% of irrigation water applied. Yet, CFI showed significantly higher yield at 100% of irrigation level. It showed that conventional furrow irrigation system gave more yield with irrigation water amount of 100%, and CFI with 85% gave optimum yield followed by AFI with 100%.

Irrigation level, in its main effect, increased bulb yield significantly ($P < 0.01$), producing higher marketable bulb yield of onion 23.769 tons ha^{-1} with full irrigation (100%) and followed by 85, 70 and 55% irrigation level with the value of 21.680 tons ha^{-1} , 19.708 tons ha^{-1} and 17.414 tons ha^{-1}, respectively. Significantly, lower bulb yield of 15.067 tons ha^{-1} was recorded with 40% of irrigation level. Among the irrigation furrow treatments, conventional furrow irrigation produced the highest bulb yield of 21.156 tons ha^{-1}, alternate furrow irrigation system (19.566 tons ha^{-1}) while fixed furrow irrigation system gave the lowest bulb yield of 17.860 tons ha.$^{-1}$

Furthermore FFI and AFI all showed a substantial decrease in bulb yield (7.51 and 15.5%, respectively). Bakker et al. (1997) and Sepaskhah and Ghasemi (2008), reported that small amount of applied water reduced yield in every other furrow irrigation (AFI and FFI) as compared to CFI due to water stress, when the same irrigation frequency was applied which supported the result of this research.

Table 6. Effect of furrow irrigation techniques and irrigation levels on Marketable bulb yield of onion (tons ha^{-1}).

Furrow techniques	Irrigation level					
	100%	85%	70%	55%	40%	Mean
CFI	26.802	23.712	20.364	19.165	15.738	21.156.2
AFI	23.640	21.939	20.033	17.084	15.137	19.566.6
FFI	20865	19.390	18.729	15.994	14.326	17.860.8
Mean	23.769	21.680.3	19.708.67	17.414.33	15.067	
LSD (0.5)	4053.4					
Cv (%)	6.8					

At P ≤ 0.05; LSD= least significant difference; CV = Coefficient of variation.

Table 7. Effect of furrow irrigation techniques and irrigation levels on unmarketable bulb yield and total bulb yield of onion (tons ha^{-1}).

Furrow techniques	UMBY	TBY
CFI	17.436	22.8999
AFI	18.381	21.4047
FFI	19.298	19.7906
LSD (P=0.05)	**148.1**	**1307.1**
Irrigation level		
100%	16.636	25.4327
85%	18.037	23.4839
70%	18.43	21.5517
55%	18.903	19.3048
40%	19.8526	17.0522
LSD (P=0.05)	225.2	-
CV (%)	8.92	6.77

At P ≤ 0.05; LSD= least significant difference; CV = Coefficient of variation.

The present result agreed with the general principle that the response of crop to full irrigation is generally higher under irrigated conditions than none irrigated one (Michael, 1978). The increment in marketable bulb yield due to application of irrigation water could be attributed to the increment in vegetative growth and increased production, which is associated with increment in leaf area index, bulb diameter and average bulb weight (Neeraja et al., 2007).

Similarly, Shoke et al. (1998) and Shock et al. (2000) indicated that the bulb and dry matter production of onion is highly dependent on appropriate water supply. Similar results were also reported by Kloss et al. (2012) who showed that dealing with improvement of water productivity is closely related to the irrigation practice of regulated deficit irrigation and has a direct effect on yield that is, if the amount of water applied decreases intentionally the crop yield will drop (Table 6).

Unmarketable bulb yield

Significantly higher unmarketable onion bulb yield was recorded when fixed irrigation furrow technique was applied with 19.29 tons ha^{-1} and followed by alternative furrow irrigation techniques, while the lowest unmarketable bulb yield of 18.38 tons ha^{-1} were recorded when convection furrow irrigation system applied with the value of 17.43 tons ha^{-} (Table 7).

There was highly significance difference among irrigation level on unmarketable bulb yield at P ≤ 0.001. The highest unmarketable bulb yield 19.85 tons ha^{-1} was recorded on irrigation level of 40% and the lowest value 1663.69 kg ha^{-1} was observed in 100% of water applied. 100% irrigation level produced 16.2, 14.07 and 9.73% lower unmarketable bulb yield of 40, 55 and 70%, respectively. In the treatments of 40 and 55% of irrigation levels, there was no observed significant difference. Similarly, there was no significant effect on unmarketable bulb between irrigation levels of 85 and 70% (Table 7).

The result revealed that, yield of very small bulbs increased with deficit irrigation. Stressed onion plants may bulb too early, produce small-sized bulbs and bulb splits and, thus, produce high amount of unmarketable yield (Kebede, 2003). This could be due to low rate of transpiration caused by stomata closer under moisture stress condition which brought about reduced photosynthesis and poor bulb growth and developments.

Corresponding to this, de Santa Olalla et al. (1994), de Santa Olalla et al. (2004) and Zayton (2007) reported that plots which received the lowest volumes of water during the development and ripening stages produced higher percentage of small size bulbs. From present result, increasing water deficit had a positive relationship with the production of high yield of under size bulbs.

Total bulb yield

Higher total onion bulb yield was recorded when convectional furrow irrigation system was applied that gave 22.899 tons ha^{-1}, and 21.404 tons ha^{-1} was recorded under alternative furrow irrigation system. The lowest total bulb yield of 19.790 tons $ha^{-1}$was recorded when fixed furrow irrigation system was applied (Table 7).

Irrigation level as the main effect is shown in Table 6 there was highly significance difference among irrigation level on total bulb yield ($P \leq 0.01$). The highest total bulb yield of 25.432 tons ha^{-1} was recorded on irrigation level of 100%ETc and followed by 23.483 tons ha^{-1}, 21.553 tons ha^{-1} 19.304 tons ha^{-1} for 85, 70 and 55% respectively. The lowest value of 17.052 tons ha^{-1} was observed in 40%ETc of water applied.

The increment in onion total bulb yield might be attributed to large size of onion bulb due to application of high level of irrigation. This is because it encourages cell elongation, above ground vegetative growth and imparts dark green colour of leaves, which is important for more assimilate production and partition that favours onion bulb growth (Brady, 1985).

The increased total bulb yield by applying full (no deficit) irrigation could have better performance on vegetative growth like plant height, number of leaves and leaf length which increase photosynthetic capacity of the plant, which in turn can improve bulb weight and contribute to increment in total bulb yield. As the irrigation level increased from 40% ETc to 100% ETc, the total bulb yield increased. This result was also in agreement with the findings of Ferreira and Carr, (2002) (Table 7).

Effects of irrigation level and furrow irrigation techniques on water use efficiency and crop water use efficiency

Irrigation level and furrow irrigation techniques had highly significant influence on water use efficiency of onion.

Crop water use efficiency (CWUE)

CWUE values with the furrow irrigation techniques ranged from 8.72 kg m^{-3} for convectional furrow irrigation while AFI and FFI had higher values of 11.76 kg m^{-3} and 10.8 kg m^{-3} respectively. The highest CWUE was recorded from alternate furrow irrigation system with value of 11.76 kg $m.^{-3}$ (Table 7). Irrigation level, in its main effect, increased CWUE ($P < 0.01$) to a higher CWUE value of 13.44 with 40% whereas 55, 70, 85 and 100% ETc irrigation levels got 11.22 kg $m,^{-3}$ 10.06 kg m^{-3}, and 9.05 kg $m^{-3}$and 8.4 kg m^{-3}, respectively. The results of this research are in agreement with Gençoglan and Yazar (1999), who reported that WUE values decreased with increasing

Table 8. Effect of furrow irrigation techniques and irrigation levels on crop water use efficiency and irrigation water use efficiency of onion (kg m^{-3}).

Furrow technique	**CWUE**	**IWUE**
CFI	8.72	6.1
AFI	11.76	8.23
FFI	10.82	7.58
LSD (P=0.05)	0.55	0.39
Irrigation level		
100%	8.4	5.88
85%	9.05	6.33
70%	10.06	7.04
55%	11.22	7.86
40%	13.44	9.41
LSD (P=0.05)	0.84	0.59
CV (%)	5.85	5.85

At $P \leq 0.05$; LSD= least significant difference; CV = Coefficient of variation.

irrigation level. In line with this result, Samson and Ketema (2007) reported that deficit irrigations increased the water use efficiency of onion. Similarly, Shock et al., (1998), Fabeiro et al. (2001), Kebede (2003), Kirnak et al. (2005) and Sarkar et al. (2008) reported that irrigation water use efficiency was higher at lower levels of available soil moisture.

Irrigation water use efficiency

The analysis of variance showed that furrow irrigation techniques as main effect was influenced by irrigation water use efficiency. The highest value of 8.23 kg/m^3 of IWUE were recorded on alternate furrow irrigation technique and 7.58 kg/m^3, 6.1 kg/m^3 obtained in FFI and CFI, respectively. In alternate furrow irrigation technique, higher value of 7.9% of WUE was obtained as compared to that of FFI and 26% of conventional furrow irrigation technique (Table 8).

IWUE significantly changed when irrigation level amount increased. However, IWUE values ranged from 5.88 kg m^{-3} for 100% irrigation level of water applied to 9.41 kg m^{-3} 40% of irrigation level of water applied. Higher IWUE values of 7.86 kg m^{-3} and 9.41 kg m^{-3}were obtained from 55 and 40%, respectively. There was no significance difference between 100% and 85% of irrigation level in IWUE.

Generally, CWUE and IWUE are influenced by crop yield potential, irrigation method, estimation and measurement of ET, crop environment, and climatic characteristics of the region. The results related to the efficiencies showed that when irrigation water is limited, 55 and 40% deficit irrigation can be applied by increasing the water use efficiencies. Mansouri-Far et al. (2010) reported that irrigation water can be conserved and yields maintained (as sensitive crop to drought stress) under water limited conditions (Table 8).

Conclusions

The most important result arisen from this investigation was that when less irrigation was applied, the conventional furrow irrigation techniques had the smallest bulb yield reduction. The highest values of plant height (46.7 cm), bulb diameter (49.9mm), leaf number per plant (9 leaves), average bulb weight per plant (64.6g) and total bulb yield (25.437 tons ha^{-}) were recorded at treatment of 100% irrigation level.

Unmarketable bulb yield was reduced as the amount of irrigation level increased. The highest unmarketable bulb yield was recorded at 40% irrigation level with the value of 19.853 tons ha^{-1} and the lowest (16.636 tons ha^{-1}) was recorded at 100% irrigation level. Both plant height and leaf number per plant showed decreases with reduction in the amount of irrigation water applied.

Smallest bulb height (42mm), lower in maturity (96days), small leaf length (28.9cm) and lower marketable bulb yield (14.326 tons ha^{-1}) were recorded at treatment combination of 40% irrigation depth with FFI. On the other hand, the bulb height (55.4mm), delay in maturity (106days), highest leaf length (40.8 cm) and higher marketable bulb yield (26.802 tons m^3) were recorded at treatment combination of 100% irrigation level with CFI.

The highest CWUE (9.41 kg mm^{-3}) of onion was obtained from 40% irrigation level and the lowest recorded from 100%ETc irrigation level with the valve (5.88 kg m^3). CWUE values of 8.23 kg ha^{-1} m^3, 7.58 kg m^3, and 6.1 kg m^3 were obtained for AFI, FFI, and CFI, respectively. Based on the results of this study, the following conclusions can be drawn:

(1) Onion bulb yield increased when irrigation level increased from 40% deficit irrigation to full application of 100%;
(2) CFI with 100% gave the highest bulb yield as compared to fixed furrow irrigation techniques and AFI gives an equivalent bulb yield at 100% with AFI and with 85% CFI. But in terms of CWUE, AFI was much better than CFI.
(3) In the study areas, water was a limiting factor, it was possible to get equivalent bulb yield and higher CWUE and IWUE when we applied 100% of irrigation level with AFI.
(4) In areas under no limitation of irrigation water, yield of Bombay Red onion variety could be improved substantially by applying 100% irrigation amount with CFI.

In conclusion, AFI can allow saving a substantial amount of water and labour without highly reduction of onion yield in the study area. This also demonstrates that crop water use efficiency will be increased by using AFI which may result in substantial benefits, under limited water condition, labour saving and improved flexibility in farm irrigation management are also expected to be achieved using AFI. This result should be of significant value in this area to irrigate additional land. However, under scarce water condition, 100% irrigation level with alternative furrow irrigation can be practiced. .

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENTS

The authors are grateful to Ethiopian Institute of Agricultural Research, for providing funds for the experiment and technical support. The authors also very grateful to Mehoni Agricultural research centre for all staff of Natural Resources Management Research core process for giving us support in field management, suggestion and technical guidance during the course of the study experiment.

REFFERENCES

Aklilu M (2009). Effects of mulching and depth of irrigation application on water use efficiency and productivity of pepper under gravity drip irrigation, MSc. Thesis, Department of Irrigation Engineering, Haramaya University, Ethiopia.

Al-Harbi AR (2002). Effect of irrigation regimes on growth and yield of onion (*Allium cepa* L.). J. King Satui Univ. 15.

Al-Moshileh AM (2007). Effects of planting date and irrigation water level on onion (*Allium cepa* L.) production under central Saudi Arabian conditions. J. Basic Appl. Sci. 8(1):14-28.

Bakker DM, Raine SR, Robertson MJ (1997). A preliminary investigation of alternate furrow irrigation for sugar cane production. Processing of the 1997 conference of the Australian Society of Sugar Cane Technologists hold at Cairns, Queensland, 29th April to 2nd May 1997, Brisbone.

Biswas SK, Sarker PK, Islam AM, Bhuiyan MA, Kundu BC (2003). Effect of irrigation on onion production. Pak. J. Biol. Sci. 6(20):1725-1728.

Boyhan GD, Granberry KT (2001). Onion production guide. The University of Georgia College of Agricultural Environmental Science. Bulletin 1198.

Cortés CF, de Santa Olalla FM, Urrea RL (2003). Production´ of garlic (*Allium sativum* L.) under controlled deficit irrigation in a semi-arid climate. Agric. Water Manage. 59(2):155-167.

Currah L, Proctor FJ (1990). Onion in Tropical Regions. Natural Resources institute. Chatham Maritime, Kent, UK. P 232.

de Santa Olalla FM, de Juan Valero JA, Cortes CF (1994). Growth and production of onion crop (*Allium cepa* L.) under different irrigation scheduling. Eur. J. Agron. 3(1):85-92.

de Santa Olalla FM, Domınguez-Padilla A, Lopez R (2004). Production and quality of the onion crop (*Allium cepa* L.) cultivated under controlled deficit irrigation conditions in a semi-arid climate. Agric. Water Manage. 68:77-89.

Dyson T (1999). World food trends and prospects to 2025. Proc. Natl.

Acad. Sci. USA 96:5929-5936.
Food and Agricultural Organization (FAO) (2002). Deficit irrigation practices. Water Reports 22. Available at: http://www.fao.org/tempref/agl/AGLW/ESPIM/CD-ROM/documents/5K_e.pdf.
Food and Agricultural Organization (FAO) (2005). AQUASTAT. FAO's Information system on water and Agriculture.
Fereres E, Connor DJ (2004). Sustainable water management in agriculture. In: Cabrera E and Cobacho R, editors. Challenges of the new water policies for the XXI century. Lisse, the Netherlands: A.A. Balkema; pp. 157-170.
Ferreira TC, Carr MKV (2002). Response of potatoes (*Solanum tuberasum* L.) to irrigation and nitrogen in a hot, dry climate: I. water use. Field Crops Res. 78(1):51-64.
Gençoglan C, Yazar A (1999). The effects of deficit irrigations on corn yield and water use efficiency. Turk. J. Agric. Forest. 23: 233-241.
Kebede W (2003). Shallot (*Allium cepa* var. ascalonicum) responses to plant nutrient and soil moisture in a sub- humid tropical climate. J. Hortic. Sci. Biotechnol. 78(4):549-555.
Kirnak H, Higgs D, Kaya C, Tas I (2005). Effects of irrigation and nitrogen rates on growth, yield, and quality of musk melon in semiarid regions. J. Plant Nutr. 28:621-638.
Kumar S, Imtiyaz M, Kumar A, Singh R (2007a). Response of onion (Allium cepa L.) to different levels of irrigation water. Agric. Water Manage. 88:161-166.
Mansouri-Far C, Sanavy SA, Saberali SF (2010). Maize yield response to deficit irrigation during low-sensitive growth stages and nitrogen rate under semi-arid conditions. Agric. Water Manage. 97:12-22.
MehARC (2015). Mehoni Agricultural Research Center, Land and water research process, Annual research report of 2014/2015, Maichew, Tigray, Ethiopia.
Otegui ME, Andrade FH, Suero EE (1995). Growth, water use, and kernel abortion of maize Subjected to drought at silking. Field Crops Res. 40(2):87-94.
Pandey RK, Maranville JW, Admou A (2000). Deficit irrigation and nitrogen effects on maize in a Sahelian environment. I. Grain yield and yield components. Agric. Water Manage. 46:1-13.
Postel SL, Daily GC, Ehrlich PR (1996). Ehrlich PR. Human appropriation of renewable freshwater. Science 271:785-788.
Sammis TW, Smeal D, Williams S (1988). Predicting corn yield under limited irrigation using plant height. Transactions of the ASAE. 3(13):830-838.
Samson B, Ketema T (2007). Regulated deficit irrigation scheduling of onion in a semiarid region of Ethiopia. Agric. Water Manage. 89:148-152.
Sarkar S, Goswami SB, Mallick S, Nanda MK (2008). Different indices to characterize water use pattern of micro-sprinkler irrigated onion (*Allium cepa* L.). J. Agric. Water Manage. 95:625-632.
Sepaskhah AR, Ghasemi M (2008). Every-other-furrow irrigation with different intervals for sorghum. Pak. J. Biol. Sci. 11(9):1234-1239.
Shock CC, Feibert EBG, Saunders LD (1998). Onion yield and quality affected by soil water potentials as irrigation threshold. Hortic. Sci. 33:1188-1191.
Shock CC, Feibert EBG, Saunders LD (2000). Irrigation criteria for drip-irrigated onions. HortScience 35:63-66.
Takele G (2009). Effect of drip irrigation levels and planting methods on yield and water use efficiency of Pepper in Bako, Western Oromia. M.Sc thesis presented to Haramaya University, Ethiopia.
Wien H (1997). Physiology of vegetable crops. In: J.L. Brewster (Ed.). Onions and Garlic, Cambridge University Press, New York. pp. 581-612.
Zayton AM (2007). Effect of soil-water stress on onion yield and quality in sandy soil. J. Agric. Eng. 24(1):141-160.

academicJournals

Vol. 12(5), pp. 114-121, May 2018
DOI: 10.5897/AJPS2018.1637
Article Number: AAD58D456949
ISSN 1996-0824

http://www.academicjournals.org/AJPS

African Journal of Plant Science

Full Length Research Paper

Comparative effects of newly introduced and adopted chemical N and P fertilizers on wheat growth, yield and yield components

Tarekegn Yoseph[1*], Tewodros Ayalew[1], Xinzhu Li[2], He Jigang[2] and Tingshuai Yan[2]

[1]School of Plant and Horticultural Sciences, College of Agriculture, Hawassa University, P. O. Box 05, Ethiopia.
[2]Kingenta Ecological Engineering Group Co., Ltd, Linyi, P. R. China.

Received 3 January, 2018; Accepted 5 April, 2018

Soil fertility decline is one of the prime factors contributing to low productivity of crops and food insecurity in Ethiopia. To alleviate this problem and achieve maximum yield, identifying suitable agronomic inputs such as N and P types in wheat production systems is very important. The aim of this study was therefore, to estimate the effects of different N and P fertilizer types and rates on growth, yield and yield components of wheat at Hawassa, southern Ethiopia. For this purpose a treatments consisting of seven N and P sources (F1=Control, F2=Local recommended Urea 100 kg ha^{-1} and DAP 100 kg ha^{-1}, F3=Urea 100 kg ha^{-1} and Enhanced DAP 100 kg ha^{-1}, F4=Black Urea 103.3 kg ha^{-1}and Enhanced DAP 100 kg ha^{-1}, F5=100 kg ha-^{1} Enhanced Urea-1 and Enhanced DAP 100 kg ha^{-1}, F6=Enhanced Urea-2 100 kg ha^{-1}and Enhanced DAP 100 kg ha^{-1} and F7=Compound fertilizer 256.25 kg ha^{-1}) were studied using a randomized complete block design with three replications. Analysis of the data recorded from the combined application of different N and P treatments revealed that maximum grain yield (3.67 t.ha^{-1}) was obtained from the plots which were supplied with Enhanced Urea-2 and Enhanced DAP at the rate of 100-100 kg ha^{-1}. It can be concluded from the result that wheat crop performed better when fertilized with this treatment. Therefore, the application of enhanced DAP 100 kg ha^{-1} with Enhanced Urea-2 100 kg ha^{-1} is recommended to optimize the growth and yield performance of wheat.

Key words: Enhanced DAP (diammonium phosphate), enhanced urea, growth, yield components, wheat.

INTRODUCTION

Ethiopia is one of the largest cereal crop producers in Africa, and the second largest wheat producer in sub-Saharan Africa, following South Africa (GAIN, 2012). Most wheat production in the country comes from small holder farmers. Wheat is primarily grown in the Southeast central and Northwest parts of the country. Small amount is produced in the rest of the North and South regions. At the national level currently 1,453,817 ha of land is covered by bread and durum wheat and over 25,376,39.8 tones are produced from this land annually (Crop Variety

*Corresponding author. E-mail: tareyoseph@gmail.com. Tel: +251929479195.

Register, 2010). Nutritionally, the crop provides an excellent source of carbohydrates, proteins (20 to 25%), fates (20 to 25%), vitamins such as:- thiamine, niacin, pantothenic acid, riboflavin and folate and minerals such as iron, magnesium, zinc and phosphate (Kumar et al., 2011). In addition to this, inclusion of wheat in the daily diet has several health benefits and can be used for different liver ailments, to help prevent cancer, tooth decay, skin problems such as eczema and psoriasis (www.organicauthority.com/benefits-of-wheatgrass.html).

It is also claimed to reduce hair from greying, improves digestion, reduces high blood pressure as it enhances the capillaries, support the growth of *lactobacilli* and can remove heavy metals from the body (Meyerowitz, 1999). It is found to improve hematological toxicity related to chemotherapy in breast cancer patients, it reduces the frequency and requirement of blood transfusions in thalassemia major (Singh et al., 2010; Arya and Kumar, 2011).

Despite, the importance of wheat and its many useful characteristics, its production is low in Ethiopia. Its average yield for example is about 2.1 t ha^{-1} which is much lower than the potential yield of 5.0 t ha^{-1} (Hailu, 1991; MoA, 2012; 2011). The low yields of wheat is partly attributed by biological and environmental factors, such as frequent occurrence of drought, declining of soil fertility, poor agronomic practice, limited and suboptimal use of production inputs, insufficient technology generation, lack of credit facilities, poor seed quality and weak supply, disease, insect, pests and weeds particularly, Striga (Spielman et al., 2011; MoA, 2012; 2011). The most important constraint that threatens wheat production in Ethiopia is poor soil fertility (CSA, 2012). Particularly, the deficiency of nitrogen (N) and phosphorus (P) is the main factor that severely reduces the growth and yield of most cereals including wheat. In order to alleviate the soil fertility problem in the area, the Bureau of Agriculture and Natural Resources of the Region has introduced chemical fertilizers particularly DAP (diammonium phosphate) and urea fertilizers in each district of the zone. However the fertilizer types and the rate which is being used by farmers are very limited and recommended in blanket basis throughout the region. Fertilizer is the most important agricultural input which contributes markedly towards final grain yield of wheat and to exploit the inherited potential of a cultivar. N is an essential component of deoxyribonucleic acid (DNA), ribonucleic acid (RNA), and proteins, the building blocks of life (Harrison, 2010). All organisms require N to live and grow. Even though N is among the most abundant elements on earth, it is the critical limiting element for growth of most plants due to its unavailability (Graham and Vance, 2000).

Several investigators (Khursheed and Mahammad, 2015; Solomon and Anjulo, 2017) reported a beneficial effect of N application on wheat. They reported that plant height, numbers of tillers, spike length, number of spikelet's and grains per spike, grain and straw yields of wheat increased with increasing N to the optimum level. P has great importance in plant nutrition. It involves in the processes of energy transformations, genetic inheritance, protein synthesis and cell division. Moreover P enhances root development and strengthening of straw, affects flowering, fruiting, seed formation and crop maturation (Gebreslassie and Demoz, 2016). Many researches reported the beneficial effect of P fertilization on growth and grain yield of cereal crops including wheat (Harfe, 2017). Kaleem et al. (2009) has also shown that the application of P fertilizer to wheat crop has significantly increased the plant height, number of tillers plant^{-1}, straw and grain yield over the control treatment. So far, little information is available on the wheat growth and yield enhancing effects of N and P fertilization in Ethiopia in general and in Southern region in particular. Therefore, the present study was aimed to evaluate the effects of newly introduced and adopted chemical N and P fertilizers on wheat growth, yield and yield components.

MATERIALS AND METHODS

Site description

The field experiment was conducted in Hawassa University research field which is located at 273 km Southwest of the capital Addis Ababa in the South Nation Nationalities and People Regional State (SNNPR). The site is located at 7^0 4'N latitude and 38^0 31'E longitude and at an altitude of 1969 m.a.s.l. The soil type of the area is sandy loam with a pH of 7.9. The average annual rainfall of the area is 800 to 1100 mm, with the average annual maximum, minimum and mean temperature of 27, 12, and 20°C, respectively (Agro-Meteorology Department, Hawassa Agricultural Research Center).

Source of inputs, plant material, treatments, experimental design and procedures

Except treatment F2 (locally used Urea and DAP fertilizers) all fertilizers were imported and obtained from the Kingenta Fertilizer Company of China. These different fertilizers were known to enhance growth and yield performances of cereals including wheat in different provinces of China. A high yielding wheat variety Jonsen, which is adapted to the agro-ecology of the area, was used for the study. Seeds were obtained from the Hawassa Agricultural Research Centre, Hawassa, Ethiopia. The variety was chosen based on its high yield ability, acceptability by farmers and seed availability. The treatments consisted of seven N and P types (F1=Control, F2=Local recommended Urea 100 kg ha^{-1} and DAP 100 kg ha^{-1}, F3= Urea 100 kg ha^{-1} and Enhanced DAP 100 kg ha^{-1}, F4=Black Urea 103. 3 kg ha^{-1}and Enhanced DAP 100 kg ha^{-1}, F5=Enhanced Urea-1 100 kg ha^{-1}and Enhanced DAP 100 kg ha^{-1}, F6=Enhanced Urea-2 100 kg ha^{-1}and Enhanced DAP 100 kg ha^{-1} and F7=Compound fertilizer 256.25 kg ha^{-1}. The size of each plot was 3 m × 4 m (12 m^2) and the distance between adjacent plots and blocks kept at 1.0 m and 1.0 m apart, respectively. Seeds were sown by drilling using a row spacing of 20 cm. The experiment was laid out using a factorial randomized complete block design (RCBD) with three replicate plots. Weeding was done manually by hoe at two weeks after seedling emergence, and three weeks later. Finally, wheat plants were harvested from the three central rows to determine yield and yield components of wheat on 27 September, 2017.

Data collected

Plant height

This was measured at mid-head setting stage by measuring ten randomly selected plants from ground level to the top of the spike termination node and averaged for a single reading.

Root length

The same sample was taken and root length was measured through measuring tape and averaged for a single mean root length in each experimental unit.

Number of tiller per plant

Tiller number was counted by ten randomly selected plants and values averaged for a single reading.

Shoot dry weight per plant

This was measured at harvest by measuring ten randomly selected plants and averaged for a single reading.

Spike length

This was measured from ten randomly selected spikes at harvest from each plot through measuring tape.

1000-grains weight (g)

This was measured at harvest and weighed on top loading digital balance and its averaged was taken as 1000-grain weight.

Grain and biological yield

Grain and biological yield were recorded at three central rows harvested in each experimental unit. Subsequent sample was oven dried at 70°C for maximum 48 h to estimate dry matter yield.

Harvest index

This was calculated as a ratio of grain yield to total biological yield.

Statistical analysis

The obtained data were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) of the Statistical Analysis System (SAS, 2002) version 9.0. Mean separation was done using Least Significant Difference (LSD) test at 5% probability level. Plants grown in non-N and P amended soil served as control.

Soil sampling and analysis

Before planting soil samples were randomly taken from the experimental site at a depth of 30 cm using an auger and the samples were mixed thoroughly to produce one representative composite sample of 1 kg. The composite soil sample was air-dried and ground to pass 2 and 0.5 mm (for total N) sieves. Then the processed sample was analyzed following standard laboratory procedures as outlined by Sahlemedhin and Taye (2000) at Hawassa University College of Agriculture soil laboratory. Organic carbon (OC) and total N contents of the soil were determined following the wet combustion method of Walkley and Black, and wet digestion procedure of Kjeldahl method, respectively. The available P content of the soil was determined following Olsen method. Soil texture was analyzed by Bouyoucos hydrometer method. The cations exchange capacity (CEC) of the soil was determined following the 1N ammonium acetate (pH 7) method. The pH (1:2.5 solid: liquid ratio) of the soils was measured in water using pH meter with glass-calomel combination electrode.

RESULTS AND DISCUSSION

Soil physico-chemical properties

The results of pre-planting soil analysis revealed that, the experimental soil is sandy loam in texture (38.0% sand, 24.0% silt and 38.0% clay). Soil texture is a fundamental soil property which in practice the farmer can do little to modify. It is also closely related to the water-holding capacity of soils, since loams and clays hold more water than sandy soils (Brady, 2002). Thus, the experimental soil has good water holding capacity, which creates a suitable growing media for cereal crops. Wheat is characteristically grown on such soils which holds sufficient amount of residual soil moisture. The soil was slightly acidic in reaction with the pH (H_2O 1:2.5) value of 6.4, which is within the range of optimum soil pH for cereal production including wheat (Havlin et al., 1999). The total N, available P, OC and CEC of the soil before planting were 0.15%, 7.6 mg kg^{-1}, 5.9%, and 24.3 cmol (+) kg^{-1}, respectively (Table 1). According to Havlin et al. (1999) soils are classified depending on their total N content in percentage (%), as very low (<0.1), low (0.1 to 0.15), medium (0.15 to 0.25), and high (>0.25). Thus, the soil of the study site has low total N content. Olsen et al. (1954) classified available P content of the range <5 as very low, 5 to 15 as low, 15 to 25 as medium and >25 mg kg^{-1} as high. According to Landon (1991) the soil organic carbon content ranges from 1 to 2, 2 to 4, and 4 to 6% are rated as low, medium and high, respectively. Thus, the OC content of the soil is considered as low before planting. The CEC ranges from 5 to 15, 15 to 25 and 25 to 40 cmol kg^{-1} are rated as low, medium and high, respectively. Based on these ratings, the cation exchange capacity (24.3 cmol kg^{-1}) before planting of the experimental field was in the medium range.

Generally the soil analysis result indicated that, the soil is nutrient deficient to support the potential crop production. This may be associated with poor farm management practices and continuous cropping with little or no fertilizers input which resulted in a decline in soil fertility. It may be because of this that growth, yield and yield components of wheat responded to supplied N and

Table 1. Physico-chemical properties of the experimental soil before planting.

pH	Organic carbon (%)	Total N (%)	Available Phosphorus (mg kg^{-1})	CEC (cmol kg^{-1})	Sand (%)	Silt (%)	Clay (%)	Textural Class
6.4	1.81	0.15	7.6	24.3	38.0	24.0	38.0	Sandy loam

Table 2. Analysis of variance for plant height, root length, number of tillers, shoot dry weight of wheat grown at Hawassa, in 2017.

Source of variation	Degree of freedom	Plant height (cm)	Root length (cm)	Number of tillers	Shoot dry weight (g)
Replication	2	2.30	1.94	0.12	0.55
Treatment	6	39.98***	9.46***	5.15***	2.82***
Error	12	4.58	0.66	0.53	0.28

*** Significant at 0.1% levels.

Table 3. Effect of different types of N and P application on plant height, root length, number of tillers and shoot dry weight of wheat grown at Hawassa, in 2017.

Treatment	Plant height (cm)	Root length (cm)	Number of tillers	Shoot dry Weight (g)
F1	34.8±0.53^{d}	6.3±0.24^{d}	5.1±0.07^{c}	8.2±0.30^{c}
F2	40.5±1.73^{bc}	9.6±0.23^{bc}	6.4±0.12^{b}	9.8±0.44^{b}
F3	39.3±0.53^{c}	9.4±0.70^{c}	6.7±0.18^{b}	9.4±0.07^{b}
F4	40.3±1.71^{c}	10.0±0.20^{bc}	8.5±0.29^{a}	10.1±0.49^{ab}
F5	41.4±0.12^{bc}	10.4±0.53^{bc}	8.1±0.87^{a}	10.1±0.32^{ab}
F6	44.1±1.67^{ab}	11.9±0.87^{a}	8.6±0.42^{a}	11.1±0.22^{a}
F7	46.3±0.79^{a}	10.9±0.53^{ab}	6.6±0.20^{b}	11.0±0.26^{a}
CV%	5.2	8.2	10.2	5.3
LSD%	3.8	1.4	1.3	0.94

Means with the same letter(s) within a column are not significantly different at p<0.05. F1 = Control, F2 = Local recommended Urea 100 kg ha-^{1} and DAP 100 kg ha-^{1}, F3= Urea 100 kg ha-^{1} and Enhanced DAP 100 kg ha-^{1}, F4 = Black Urea 103. 3 kg ha-^{1}and Enhanced DAP 100 kg ha-^{1}, F5 = 100 kg ha-^{1} Enhanced Urea-1 and Enhanced DAP 100 kg ha-^{1}, F6 = Enhanced Urea-2 100 kg ha-^{1} and Enhanced DAP 100 kg ha-^{1} and F7= compound fertilizer 256.25 kg ha-^{1}.

P fertilizers in the present experiment.

Plant height

Different types of N and P fertilizer had highly significant effects on the plant height (Table 2). The highest mean plant height was obtained from plots supplied with treatment F7 (compound fertilizer) (46.3 cm) which was significantly different from the other treatments, except F6 (Table 3). The lowest plant height (34.8 cm) was recorded from the treatment F1 (control), which was significantly inferior to all other treatments. Plant height increment of 87.5% was obtained from F7 as compared to the F2 (locally used urea and DAP) fertilizers. The reasons for the increased plant height under different N fertilizer types could be due to the increased vegetative growth with applied N. In line with this, Razaq et al. (2017) obtained increased plant height of wheat fertilized with N. Similarly, Abera (2013) reported that applied N at different rates resulted in increased vegetative growth period of maize that increases photosynthetic assimilate production and its partitioning to stems that might have favorable impacts on heights of maize. On the other hands, increase in plant height due to application of P might be attributed to more availability of nutrients due to increased levels of P, which exerted beneficial effect on vegetative growth of plant. Increase in plant height with supplied N and P levels has also been observed by Khan et al. (2014). This may be due to increased root growth, which strengthened the stem against lodging during prolonged vegetative growth. Furthermore, Khalil et al. (1988) and Umeri et al. (2016) reported that marked increase in plant height of maize due to combined application of NP fertilizers.

Root length plant^{-1}

Statistical analysis of data revealed significant effects of

Table 4. Analysis of variance for yield and yield components of wheat grown at Hawassa, in 2017

Source of variation	Degree of freedom	Spike length (cm)	1000 grain weight (g)	Grain yield (t. ha^{-1})	Biological yield (t. ha^{-1})	Harvest index
Replication	2	3.53	22.33	0.17	0.08	0.006
Treatment	6	21.06***	166.89**	2.09***	2.92***	0.03**
Error	12	1.87	31.39	0.15	0.19	0.004

*** and ** Significant at 0.1 and 1% levels, respectively.

different N and P fertilizer types on root length $plant^{-1}$ (Table 2). Maximum mean root length $plant^{-1}$ was obtained from the F6 (11.9 cm) and it was significantly different from all other treatments except treatment F7 which in turn was not significantly different from treatments F2, F4 and F5 (Table 3). The lowest root length $plant^{-1}$ (6.3) was recorded from F1 (control). All other N and P fertilizer treatments increased root length $plant^{-1}$ to a variable extent over the control, indicating that the need of N and P sources for better root growth in nutrient deficient soils. The increased root growth beneficially increases the potential soil water and nutrient reservoirs of the growing crops (Gajri et al., 1989). Studies in wheat have reported that applications of N fertilize, typically increase water use efficiency in both irrigated (Hussain and Al-Jaloud, 1995) and rain-fed systems (Belford et al., 1987). P also plays an important role in lateral root morphology and root branching and influences not only root development, but also the availability of N nutrients (Lopez-Bucio et al., 2003; Jin et al., 2005). Similar to these results Razaq et al. (2017) reported an increased root growth due to supplied N and P fertilizers.

Number of tillers $plant^{-1}$

Analysis of variance on tiller number $plant^{-1}$ revealed the existence of highly significant difference among the combined application of N and P fertilizers (Table 2). Maximum mean number of tillers $plant^{-1}$ was obtained from the treatment F6 and it was significantly at par with treatments F3 and F4 (Table 3). The lowest tiller number per plant (5.1) was recorded from the control treatment. This study is supported by Tabar (2013) where application of N and P fertilizers found to favor tillering in rice. Wakene et al. (2014) also reported an increased number of fertile tillers, total biomass and straw yield of barley due to addition of P.

Shoot dry weight $plant^{-1}$

Plant growth measured as shoot dry matter was significantly (P<0.001) affected by combined application of N and P fertilizers (Table 2). The highest (11.1 g $plant^{-1}$) shoot dry matter was recorded from treatment F6, but statistically parity between this treatment and treatments F7, F4 and F5 (Table 3). However, the lowest shoot dry weight (8.2 g) was recorded from treatment F1 (control). This is in agreement with the findings of Elgharably (2011) who stated an increased shoot dry matter of wheat due to individual and combined application of N and P in a saline sandy loam soil.

Spike length $plant^{-1}$

Application of different types of N and P fertilizers significantly increased spike length (Table 4). The highest spike length (14.5 cm) was recorded from the application of treatment F6 (Enhanced Urea-2 100 kg $ha^{-1}$and Enhanced DAP 100 kg ha^{-1}). However, statistically significant variation in spike length was not detected between this treatment and treatment F7 (Table 5). However, these treatments were significantly higher over the control. These results are similar with the findings of Kaleem et al. (2009) who reported maximum NP fertilizer utilization recorded the highest yield effects due to maximum accumulation of photosynthates. The length of spikelets per spike plays a paramount role towards the grain per spike and final yield of wheat crop (Shahzad et al., 2007).

1000- grains weight

The data given in Table-4 showed that there were highly significant (P<0.01) variations in fertilized and non-fertilized treatments for 1000-grain weight. Maximum 1000 grain weight (55.7 g) was obtained from plots treated with enhanced urea and DAP at 100-100 kg ha^{-1}. However, the minimum (30.7 g) 1000-grain weight was obtained from the treatment where NP was not supplied (Table 5). All the other treatments fall in between these treatments. The relatively heavier seed weight in N and P treated plots was obtained possibly due to increased assimilates production and photosynthesis efficiency at the grain filling stage of the plant because of improved plant mineral nutrition. Furthermore, it may be due to greater contribution of N and P by producing healthy grains which have well filled and bigger grains than the

Table 5. Effect of different types of N and P application on yield and yield components of wheat grown at Hawassa, in 2017.

Treatment	Spike length (cm)	1000grain weight (g)	Grain yield (t. ha^{-1})	Biological yield (t. ha^{-1})	Harvest index
F1	6.0±0.40^{d}	30.7±1.86^{c}	0.92±0.17^{c}	2.67±0.26^{d}	0.34±0.03^{b}
F2	10.9±0.73^{bc}	42.0±1.53^{b}	2.37±0.32^{b}	4.25±0.11^{c}	0.55±0.06^{a}
F3	10.2±0.70^{c}	41.7±2.19^{b}	2.41±0.04^{b}	4.33±0.19^{bc}	0.56±0.03^{a}
F4	11.7±0.55^{bc}	44.3±3.28^{b}	2.78±0.21^{b}	5.07±0.19^{ab}	0.55±0.05^{a}
F5	11.3±1.54^{bc}	44.0±4.00^{b}	2.94±0.02^{b}	5.07±0.19^{ab}	0.58±0.02^{a}
F6	14.5±0.94^{a}	55.7±3.28^{a}	3.67±0.37^{a}	5.81±0.32^{a}	0.63±0.04^{a}
F7	12.9±0.44^{ab}	47.3±4.70^{ab}	2.74±0.18^{b}	4.66±0.36^{bc}	0.59±0.02^{a}
CV%	12.4	12.8	15.0	9.7	12.3
LSD%	2.4	10.0	0.7	0.78	0.12

Means with the same letter(s) within a column are not significantly different at $p<0.05$. F1 = Control, F2 = Local recommended Urea 100 kg ha-^{1} and DAP 100 kg ha-^{1}, F3= Urea 100 kg ha-^{1} and Enhanced DAP 100 kg ha-^{1}, F4 = Black Urea 103. 3 kg ha-^{1}and Enhanced DAP 100 kg ha-^{1}, F5 = 100 kg ha-^{1} Enhanced Urea-1 and Enhanced DAP 100 kg ha-^{1}, F6 = Enhanced Urea-2 100 kg ha-^{1} and Enhanced DAP 100 kg ha-^{1} and F7= compound fertilizer 256.25 kg ha-^{1}.

control treatments. These results are similar with the findings of Khan et al. (2014) who reported improved seed weight due to combined application of NP fertilizers on maize.

Grain yield

The fertilizer treatments significantly affected the grain yield of wheat (Table 4). The yield was highest in the F6 treatment, followed by treatments F5, F7, F3 and F2, respectively. In the F1 (control), the yields of wheat was significantly lower than those other treatments. On the other hands, it was visually observed that wheat plants in the control plots were very thin with small spike size, short and light in color. Whereas, plants in the N and P fertilized plots had thick and strong stems, green in color, large spike size. The increased grain yield due to applied N and P might be attributed to low nutrient contents of study site (Table 1). Thus, the availability of these nutrients enables the plant to develop more extensive root system to extract water and nutrients, from more depth. This could enhance the plants to produce more assimilates, which was reflected in higher biomass (Gobarah et al., 2006). Furthermore, the increases in yield due to P fertilizer may be attributed to the activation of metabolic process, where its role in building phospholipids and nucleic acid is known (Gentili and Huss-Danell, 2003). This result is in agreement with the findings of Bereket et al. (2014) who reported that application of N and P fertilizers increase grain yield of wheat. These results do not agree with the findings of Kulhare et al. (1991) who studied NP doses effect on late sown wheat crop and reported that application of NP, does not increased wheat yield.

Biological yield

Application of different types of N and P fertilizer had highly significant effects on the biological yield of wheat (Table 4). Highest biological yield of (5.81 t. ha^{-1}) was obtained from treatment F6 but was not statistically different than the treatments F4 and F5 (Table 5). The lowest biological yield (2.67 t ha^{-1}) was recorded from the control, which was significantly inferior to all other treatments. Greater plant height, yield and yield components might have contributed to the differences observed in biological yield among the different types of N and P application. These results are in confirmation with the findings of Islam and Baten (1987) and Patel et al. (1991) who recorded maximum biological yield by the application of optimum N and P fertilizer rates when compared to the treatments receiving no N and P fertilizers.

Harvest index

Harvest index was influenced significantly by different N and P fertilizers treatments (Table 4). The highest harvest index (0.63) was recorded in F6 and it was at par with all the treatments except the control. The lowest harvest index (0.34) was recorded from the control treatment (Table 5). The physiological ability of a crop plant to convert proportion of dry matter into economic yield is measured in terms of harvest index. The results indicated that adequate supply of N and P fertilizers in combination enhanced dry matter partitioning in favor of grain showing a greater harvest index. This is illustrated by the lower harvest indices observed under the treatments that received no N and P treatments. These results corroborate the findings of Mesfin and Zemach (2015), who reported similar results.

Conclusion

In this study it was found that, the combined application of N and P fertilizers had significant effect on growth, yield and yield components of wheat. Among the treatments studied, Enhanced Urea-2 and enhanced DAP 100 kg ha^{-1}, respectively gave greater grain yield. Furthermore, this treatment enhanced growth and yield related parameters compared to the control treatment. Thus, it is possible to recommend the combined application of Enhanced Urea-2 and Enhanced DAP at the rate of 100 kg ha^{-1} each to attain greater grain yield of wheat in the study area. However, it is advisable to undertake further research across soil type, years and locations to draw sound recommendation on a wider scale.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENTS

The authors are grateful to Kingenta Fertilizer Company for supplying enhanced N and P fertilizers and for financial support to conduct this experiment.

REFERENCES

Abera K (2013). Growth, productivity and nitrogen use efficiency of maize (*Zea mays* L.) as influenced by rate and time of nitrogen fertilizer application in Haramaya District, Eastern Ethiopia and extension needs. Field Crops Res. 65:93-106.

Arya P, Kumar M (2011). Chemoprevention by (*Triticum aestivum* L.) of mouse skin carcinogenesis induced by DMBA and croton oil-association with oxidative status. Asian Pac. J. Cancer Prev. 12:143-148.

Belford RK, Klepper B, Rickman RW (1987). Studies of intact root-shoot systems of field grown winter wheat-II. Root and shoot developmental patterns as related to nitrogen fertilizer. Agron. J. 79:310-319.

Bereket H, Dawit H, Mehretab H, Gebremedhin G (2014). Effects of Mineral Nitrogen and Phosphorus Fertilizers on Yield and Nutrient Utilization of Bread Wheat (*Tritcum aestivum*) on the Sandy Soils of Hawzen District, Northern Ethiopia. Agric. Forest. Fish. 3(3):189-198.

Brady NC (2002). Phosphorus and potassium. In. Brady, N.C. and Weil, R.R. (eds.) The Nature and Properties of Soils. Dehli, India: Prentice-Hall. pp. 261-272.

Crop Variety Register (2010). Animal and plant health regulatory directorate. Issue No. 12, Addis Ababa, Ethiopia.

Central Statistical Agency (CSA) (2012). Agricultural sample survey: area and production of major crops, meher season. Vol. I. Addis Ababa, Ethiopia.

Elgharably A (2011). Wheat Response to Combined Application of Nitrogen and Phosphorus in a Saline Sandy Loam Soil. Soil Sci. Plant Nutr. 57:396-402.

Global Agricultural Information Network (GAIN) (2012). Assessments of commodity and trade issues made by USDA staff and not necessarily statements of official U.S. government policy. Report number ET 1201.

Gajri PR, Prihar SS, Arora VK (1989). Effects of nitrogen and early irrigation on root development and water use by wheat on two soils. Field Crops Res. 21(2):103-114.

Gebreslassie HB, Demoz HA (2016). A Review on: Effect of Phosphorus Fertilizer on Crop Production in Ethiopia. J. Biol. Agric. Healthc. 6(7):117-120.

Gentili F, Huss-Danell K (2003). Local and systemic effects of phosphorus and nitrogen on nodulation and nodule function in Alnus incana. J. Exp. Bot. 54:2757-2767.

Gobarah ME, Mohamed MH, Tawfik MM (2006). Effect of phosphorus fertilizer and foliar spraying with zinc on growth, yield and quality of groundnut under reclaimed sandy soils. J. Appl. Sci. Res. 2(80):491-496.

Graham PH, Vance CP (2000). Nitrogen fixation in perspective: an overview of research and extension needs. Field Crops Res. 65(2-3):93-106.

Hailu GM (1991). Wheat productions and research in Ethiopia. IAR, Addis Ababa.

Harfe M (2017). Response of bread wheat (*Triticum aestivum* L.) varieties to N and P fertilizer rates in Ofla district, Southern Tigray, Ethiopia. Afr. J. Agric. Res.12(19):1646-1660.

Harrison JA (2010). The Nitrogen Cycle.Visionlearning Vol. EAS-2 (4).

Havlin JE, Beaton JD, Nelson, WL, Tisdal SL (1999). Soil Fertility and Fertilizers. An Introduction to Soil Management, 6th ed. Prentice Hall, Inc. 634p.

Hussain G and Al-Jaloud AA (1995). “Effect of irrigation and nitrogen on water use efficiency of wheat in Saudi Arabia,” Agricultural Water Management, 27(2): 143–153.

Islam MA and Baten MA (1987). Growth and yield of wheat as affected by different levels of N and P. Thai J. Agri. Scie. 20 (3) Absts. 42(6): 3886-1989.

Jin J, Wang GH, Liu, X, Pan X, Herbert SJ (2005). Phosphorus application affects the soybean root response to water deficit at the initial flowering and full pod stages. Soil Sci. Plant Nutr.51(7):953-960.

Kaleem S, Ansar M, Ali MA, Sher A, Ahmad G and Rashid M (2009). Effect of phosphorus on the yield and yield components of wheat variety “inqlab-91” under rainfed conditions. Sarhad J. Agri. 25(1): 21-24.

Khalil SK, Afridi MS and Iqbal M (1988). Plant height, weeds weight and hay yield of maize and Mungbean in mono and associated culture as affected by NPK application. Sarhad J. Agri. 4: 377-85.

Khan F, Khan S, Fahad S, Faisal S, Hussain S, Ali S, Ali A (2014). Effect of Different Levels of Nitrogen and Phosphorus on the Phenology and Yield of Maize Varieties. Am. J. Plant Sci. 5:2582-2590

Khursheed MQ, Mahammad MQ (2015). Effect of different nitrogen fertilizers on growth and yield of wheat. Zanco J. Pure Appl. Sci. 27(5):19-28.

Kulhare PS, Agarwal KK and Padihar SK (1991). Response of N. P. and Zn by late sown wheat in deep vertisoles. Curreny Res. Univ. Agric. Sci. Banglor. 20(10):217-218.

Kumar P, Yadava RK, Gollen B, Kumar S, Verma RK, Yadav S (2011). Nutritional Contents and Medicinal Properties of Wheat: A Review. pp. 1-9.

Landon JR (1991). Booker tropical soil manual: a handbook for soil survey and Agricultural land evaluation in the tropics and subtropics. Long man scientific and technical. Booker Tate Ltd. John Wiley and Sons, Inc., New York.

Lopez-Bucio J, Cruz-Ramirez A, Herrera-Estrella L (2003). The role of nutrient availability in regulating root architecture. Curr. Opin. Plant Biol. 6(3):280-287.

Mesfin K, Zemach S (2015). Effect of Nitrogen and Phosphorus Fertilizer Rates on Yield and Yield Components of Barley (*Hordeum Vugarae* L.) Varieties at Damot Gale District, Wolaita Zone, Ethiopia. Am. J. Agric. Forest. 3(6):271-275.

Meyerowitz S (1999). Wheat Grass: Nature’s Finest Medicine, Edition 6, Sproutman Publications, pp. 31-33.

MoA-Ministry of Agriculture (2011). Ministry of Agriculture. Animal and Plant Health Regulatory Directorate. Crop variety register, Issue No. 14. Addis Ababa, Ethiopia.

Ministry of Agriculture (MoA) (2012). Ministry of Agriculture. Animal and Plant Health Regulatory Directorate. Crop variety register, Issue No. 15. Addis Ababa, Ethiopia.

Olsen SR, Cole CV, Wantanabe FS and Dean LA (1954). Estimation of available phosphorous in soils by extraction with sodium bicarbonate, U.S. Dep. of Agriculture circular 939. U.S.D.A, Washington DC., USA. P 23.

Patel NM, Patel RB, Patel KK (1991). Response of wheat varieties to N and P. Indian J. Agron. 36:255-256.

Razaq M, Zhang P, Shen H-l, Salahuddin (2017). Influence of nitrogen and phosphorous on the growth and root morphology of *Acer mono*. PLoS ONE 12(2):e0171321.

Sahlemedhin S, Taye B (2000). Procedures for soil and plant analysis. National Soil Research Center, Ethiopian Agricultural Research Organization, Addis Ababa, Ethiopia.

SAS Institute Inc. (2002). SAS User's Guide, Statistics Version 9.0 ed. SAS Institute, Cary, NC, USA.

Shahzad MA, Din WU, Sahi ST, Khan MM, Ehsanullah and Ahmad M (2007). Effect of sowing dates and seed treatment on grain yield and quality of wheat. Pak. J. Agric. Sci. 44(4):581-583.

Singh K, Pannu MS, Singh P, Singh J (2010). Effect of Wheatgrass tablets on the frequency of blood transfusions in Thalassemia major. Indian J. Pediatr. 77(1):90-91.

Solomon W, Anjulo A (2017). Response of bread wheat varieties to different levels of nitrogen at Doyogena, Southern Ethiopia. Int. J. Sci. Res. Publ. 7(2):452-459.

Spielman DJ, Kelemwork D, Alemu D (2011). Seed, fertilizer, and agricultural extension in Ethiopia. ESSP II Working Paper 020. International Food Policy Research Institute (IFPRI).

Tabar (2013). Effect of Nitrogen and Phosphorus FertilizerManagement on Growth and Yield of Rice. Int. J. Agric. Crop Sci. 5(15):1659-1662.

Umeri C, Moseri H, Onyemekonwu RC (2016). Effects of Nitrogen and Phosphorus on the Growth Performance of Maize (*Zea mays*) in Selected Soils of Delta State, Nigeria. Adv. Crop Sci. Technol. 4: 207.

Wakene T, Walelign W, Wassie H (2014). Effects of Nitrogen and Phosphorus Fertilizer Levels on Growth and Development of (*Hordeum vulgare* L.) at Bore District, Southern Oromia, Ethiopia. Am. J. Life Sci. 2(5): 260-266.

www.organicauthority.com/benefits-of-wheatgrass.html. Accessed on October 23, 2017.

Related Journals: