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THE PERFORMANCE OF TRUE SEED SHALLOT LINES UNDER DIFFERENT ENVIRONMENTS OF ETHIOPIA

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Abstract: Seven true seed shallot lines were evaluated for 3 years at 3 locations to determine their performance and stability. Stability differences were assessed on the basis of linear regression of the lines on environmental index and on deviation from linear function along with the mean yield. The combined analysis showed that bulb yield over 9 environments ranged from 15.1 to17.5 t ha^{-1} with overall mean yield of 16.5 t ha^{-1}, and lines Vethalam, Tropix, Dz-94 and Athlas gave the highest mean yield. The combined analysis of variance showed significant ($p<0.05$) genotype and genotype by environment effects on bulb yield. The regression coefficient for bulb yield ranged from 0.72 to 1.36. The regression coefficient of two high yielding lines (Vethalam and Athlas) was above 1, and was higher in environments where growing conditions were favorable. High and significant deviations were obtained for lines Tropix and Athlas and these lines were found unstable to change in environment. However, line Tropix showed specific adaptation to low yielding environments of Kulumsa and Melkassa. The best line Vethalam with a small deviation from regression was found widely adaptable to different environments and it was released with local name 'Yeras' to be grown in Rift Valley and similar areas in Ethiopia.

Key words: shallot, environment, stability, seed, yield.

Introduction

Shallot (*Allium cepa* var. *aggregatum*) is one of the most widely cultivated bulb crops in Ethiopia. The production of bulb shallot is restricted to highland areas under rain-fed conditions. It is one of the most important cash crops and traditionally produced under rain-fed conditions in many regions of the country (Hararghe, Shoa, Arsi, Bale, Gojjam, etc.) by small farmers as income generating spice crop for flavoring local dishes. However, the crop has a wide range of climatic and soil adaptations and is cultivated both under rain-fed and irrigated conditions. Nevertheless, it is mostly produced and adapted in areas where the

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climate is humid (rainy season) and where the growing season is short (Getachew and Asfaw, 2004). This crop has very short growing season of about 3 months, which allows it to be grown between other crops or during the short rainy season. Nevertheless, currently the crop is widely grown in irrigated conditions of the Rift Valley areas. Thus, its cultivation and distribution to new areas showed its potential for further expansion and improvement in the country (Lemma and Shimeles, 2003).

The national average yield of bulb shallot is about 7 t ha^{-1} and the bulb yield is characterized by poor quality of mixed varieties varying in size, color, shape and storability. Moreover, diseases, insects and lack of improved pre- and post-harvest management practices have also contributed to low yield and quality (Getachew and Asfaw, 2004). However, the main constraint to shallot production in the country is the need of high amount of planting material of 1.5–2 t ha^{-1} of edible bulbs which comprises about 40% of cost of production compared to 4–5 kg ha^{-1} of true seed (Lemma and Yayeh, 1994).

The farmers are usually forced to sell all the produce either directly on the farms or immediately after harvest mainly due to the need of immediate cash return and storage problems. This has resulted in difficulty to obtain planting materials at the peak planting time and farmers are forced to buy planting material of any kind available in the market at a very high price, which is in most cases transported from long distances. This causes some farmers to keep their own seed bulbs tight into bunch and to keep them above the stove in the kitchen for 3 to 5 months. In addition, using such vegetative propagated materials also promotes diseases, viruses, fungi, bacterial pathogens and nematodes (Currah and Proctor, 1990). Therefore, to tackle this problem, research effort was made at Melkassa to grow shallot from true seed as a good option for the grower to avoid the storage problems and to get disease-free planting material. Shallot crops, when produced from true seed, have many advantages in the amount of planting materials required, and giving growers the chance to easily handle planting materials and also to avoid the problems of transporting and storing large quantity of bulbs.

Since shallot crop meets a great demand as cash crop, attempt was made in preliminary studies to investigate potential of bulb yield from true seed in order to address one of the barriers to produce the crop. As shallot lines grown from true seed gave better yield and bulb quality at Melkassa Research Center, a multi-location trial was initiated to further verify the performances of these lines under different agro-ecological conditions of the country (MARC, 2005). As in every plant-breeding program, breeders have to plant materials for a number of years in various locations in order to test stability of materials over a range of environments (Yan and Hunt, 1998). The performance of crop plants varies in different environments, which indicates their adaptability to specific region or over wide areas (Khan et al., 2002). Yield stability of promising genotypes over different

environments is very important in breeding strategy for varieties to be released nationally for wide or specific adaptation. Though there are several stability measures that can be used as selection and evaluation criteria, the method developed by Eberhart and Russel (1966) was used to classify varieties for yield stability. Yield response and stability must be heritable, repeatable and provide information useful to the breeder (Becker and Leon, 1988). Although there is a lot of work on stability analysis on other crops, there is virtually no information on stability of true seed shallot genotypes promising for national release in Ethiopia.

Therefore, the objectives of this study were to identify widely adaptable true seed shallot lines under different environments and to assess the magnitude and nature of genotype by environment interaction on yield and quality of true seed shallots lines tested across different environments.

Material and Methods

Seven true seed shallot lines: Tropix, Atlas, Roxa (from Holland), Vethalan (Sri Lanka), GS-106 (Merti state enterprise) and two local selections (Dz-78 and Dz-94) were evaluated in multi-location trial at Melkassa, Zewai (dry land irrigated areas) and Kulumsa (highland) for 3 years and a trial within a year was considered as one environment and these totally made 9 environments (Table 1).

Table 1. Altitude, temperature, rainfall and soil type of experiment sites.

Location	Altitude (m)	Mean temperature (°C)		Rainfall (mm)	Soil type
		Min	Max		
Melkassa	1,550	14	28	770	Sandy loam
Zewai	1,670	15	32	710	Silty loam
Kulumsa	2,130	11	23	850	Brownish clay soil

Seedlings of all the cultivars were raised in nursery bed and transplanted after 45 days in to experimental plots in all the 3 locations. The seedlings were planted on a plot size of 2.8 x 3 m with the recommended spacing for onion using double rows of 40 cm between water furrows, 20 cm between rows and 10 cm between plants. The materials were arranged in a randomized complete block design with 4 replications. Fertilizer diammonium phosphate (DAP) was applied at the rate of 200 kg ha^{-1} during planting and split application of urea at the rate of 100 kg ha^{-1} was used, half during transplanting and the rest was side dressed one and half month after transplanting. The two common diseases – purple blotch (*Alternaria porri*) and downey mildew (*Peronospora destructor*) were controlled by applying Ridomil MZ at the rate of 3 kg ha^{-1} with an 8-day interval. The common insecticide Celecron at the rate of 0.5 l ha^{-1} was used to control thrips (*Thrips tobaci*). Harvesting was done when 75% of the tops had fallen down. The harvested bulbs

were cured for 3 days in the field before cutting the necks. Parameters like plant height, flower stalk and leaf number, bulb yield (marketable and total), bulb size, number of bulb splits, and TSS (total soluble solids) were recorded.

The combined analysis of variance over years and locations was computed using SAS/STAT Software 9.2 computer program (SAS Institute Inc., Cary, NC, USA). Mean separation was done using Duncan's multiple range test (DMRT). Analysis of variance, stability parameters, linear regression coefficient (b_i) and deviation from regression of lines measured over environmental index $S_i^2d_j$ were computed as suggested by Eberhart and Russel (1966) using the model $Y_{ij} = \mu_i + B_iI_j + \delta_{ij}$. The stability of varieties was defined by high mean yield, regression coefficient (b_i=1) and deviation from regression as small as possible (δ_{ij}=0). The stability parameters were estimated by the following formulae:

$M = S_iY_{ij}/n$

$B_i = S_iY_{ij}/I^2j$

$S^2d_i = (S_iS^2_{ji}/n\text{-}2) – S^2\ e/r$

Where: n = Number of environments,

S_iY_{ij}/I^2_j = Sum of the squares of deviation from the regression,

S^2e/r = Estimate of pooled error.

Results and Discussion

From individual location analysis, the highest mean bulb yield was obtained in Zewai (19 t ha^{-1}) followed by Kulumsa and Melkassa (15.3 and 15.1 t ha^{-1}) respectively. At Melkassa, the overall yield range was 13.5–17.1 t ha^{-1} and Atlas gave significantly higher yield (17.1 t ha^{-1}) than all the rest of the lines, except for Tropix which was not significantly different from Athlas (Table 2).

Table 2. Yield, morphological and quality characteristics of true seed shallot.

Shallot lines	Yield (t ha^{-1})				Plant height (cm)	No. of flower stalks per plant	Leaf number per plant	Number of splits per plant	Soluble solids (%)	Bulb weight (g per plant)
	Melkassa	Kulumsa	Zewai	Combined mean						
Roxa	15.1bc	14.2ns	16.7c	15.0b	44.38	5.0	16.3	2.45	16	60
Tropix	16.0ab	15.1	20.5a	17.2a	43.63	6.5	16.4	2.85	16	63
Vethalam	15.7bc	16.4	20.7a	17.5a	47.10	4.9	16.9	3.15	16	62
GS-106	13.5d	15.9	18.6abc	16.0ab	60.25	5.7	15.7	2.85	18	55
Dzt-78	13.6d	15.5	17.5bc	15.6b	64.25	5.5	16.2	3.20	15	55
Dzt-94	14.7c	15.0	19.6ab	16.5ab	44.63	5.8	17.9	2.85	16	66
Atlas	17.1a	15.2	19.4ab	17.3a	53.13	6.5	18.1	3.00	15	58
Mean	15.1	15.3	19.0	16.5	48.20	5.7	16.8	3.00	16	60

In the highland areas of Kulumsa, the yield range was from 14.2–16.4 t ha^{-1} and the differences between lines were not statistically significant. However, at Zewai, Vethalam gave the highest yield of 20.7 t ha^{-1} followed by Tropix (20.5 t ha^{-1}) and this was significantly different from local selections – Dz-78 and Roxa, which indicated that the sandy loam soil of Zewai seems favorable for high bulb yield of true seed shallot.

The combined analysis of variance showed that there was a significant difference among the genotypes and genotypes × environment interactions at $P< 0.05$ (Table 3). This showed that the lines differed in response to change in the environment. The overall mean yield range of the lines was 15.0–17.5 t ha^{-1}. Shallot lines Vethalam, Tropix, Dz-94 and Athlas gave the yield which was higher than the overall mean yield of 16.5 t ha^{-1} (for all the environments). The shallot lines Vethalam, Tropix and Athlas gave significantly higher mean yield than Roxa and Dz-78, but these lines were not significantly different from the rest of the lines, which indicated there was no huge difference among all lines as they produced good bulb yield.

Table 3. Analysis of variance of stability of 7 shallot cultivars in 9 environments.

Source of variation	DF	SS	MS
Varieties	6	160.3	26.7**
Environments + (varieties + environments)	56	888.3	
Environments (linear)	1	780.22	
Varieties × environments (linear)	6	34	5.73*
Pooled deviation	49	74	1.51
Pooled error	162	-	14.42

** Significant at $P<0.01$, * significant at $P<0.05$.

The effect of years on yield performance of shallots indicated that the highest mean yield was recorded at Zewai during these two years (year 1 and year 3) which was considered the best yielding environment with high positive environmental index of (6.5 and 5.7 respectively) and yield potential of 22.6 and 22.2 t ha^{-1} respectively. Nevertheless, Melkassa only in year 3 produced positive environmental index with yield potential of 18 t ha^{-1} which is higher than the overall mean yield (16.5 t ha^{-1}) of 9 environments.

At Kulumsa, in all the three years of the experimental period, there was negative environmental index which indicated that it is the poorest yielding environment for true seed shallot. However, the performance of shallot lines was good during year 2 in this location due to low rainfall distribution which created favorable conditions for shallot performance in the highland areas where better mean yield of 15.7 t ha^{-1} was obtained during this year. This indicated that when there was a shortage of rain, shallot lines performed better at the highland heavy soils than at the lowland sandy soils.

The mean number of split bulbs/plant ranged from 2.5 to 3.2 for the lines Roxa to Dz-78 and Vethalam. This character is very good measurement of shallot bulb quality and the potential indicator for identification of shallot lines from single bulb onion crop. From all shallot lines, Vethalam and Dz-78 gave a higher number of split bulbs than the rest of the lines. The study of Tabor et al. (2006) showed that shallots grown from seeds or seedling clusters contain on average of 1–3 bulb splits per plant.

In this experiment, except Dz-78 and Athlas, all the lines gave TSS greater than 15%, indicating that they have high dry matter and pungency content which is highly preferred quality by the consumers. The average single bulb weight ranged from 55 to 66 g and shallot lines Dz-94, Tropix and Vethalam gave high average bulb weight with a higher number of splits/plant than the rest of the lines. According to the study of Dereje et al. (2012), using four local shallot varieties produced in Ethiopia by the local farmers, the local check (farmers' variety) gave the highest dry matter and TSS content compared to the released varieties 'Minjar', 'Negelle' and 'Huruta', which might be attributed to their wider genetic variation, and breeding them with this local variety for high dry matter content, total soluble solid, and better bulb skin color is advisable for the future. However, for such breeding program, the seed production potential of these varieties needs to be assessed which would also be a prospect to solve shallot production and expansion constraints by alleviating the shortcomings of using edible bulbs as a planting material.

From the stability analysis, linear regression of a single line on the average yield of all lines in each environment resulted in regression coefficient ranging from 0.72 to 1.36 for bulb yield (Table 4). This large variation in regression coefficient explains different responses of genotypes to environmental changes.

Table 4. Mean yield and stability parameters of 7 shallot cultivars tested in 9 environments.

Cultivar	Mean yield (t ha^{-1})	b_i	S^2d
Roxa	15.1	0.72**	0.30
Tropix	17.2	0.79	0.63*
Vethalam	17.5	1.13	0.19
GS-106	16.0	0.99**	0.36
DZ-78	15.2	0.87*	0.31
DZ-94	16.5	1.36**	0.12
Athlas	17.0	1.14	1.19**
Pooled mean	16.5		

** Significant at P<0.01, * significant at P<0.05.

Most shallot lines showed regression coefficient b_i to be significantly different from unity, which indicates that the linear response of the lines to environmental

index is different in different environment. Though the regression coefficient of low yielding lines was significant, the top yielding lines (Vethalam and Dz-94) had a regression coefficient above 1 with a small deviation from regression (δ_{ij}=0), which indicated that these lines possessed good stability in different growing conditions. However, the deviation from the linear function was significant (δ_{ij}=0) for Tropix, whereas highly significant for Athlas indicating their wide fluctuation to the change in environment. Although Tropx gave bulb yield above the grand mean, its regression coefficient was less than 1 indicating its specific adaptation to low yielding environments of Kulumsa and Melkassa. However, Athlas gave higher mean yield and regression coefficient above 1 indicating its high yielding potential under highly favorable conditions. However, they were considered as the most unstable lines from all shallot lines tested in this study.

Moreover, lines Roxa and Dz-78 produced bulb yield below the grand mean, but had a regression coefficient below 1 indicating resistance to changing environment and they were considered as well adapted lines to poor environments and further evaluation of these lines is needed in similar environments of Kulumsa and other areas. The improved genotypes should have the characteristics of wider adaptability across a range of diverse environments. However, unstable varieties are major source of risks (Javed et al., 2006). The phenotypic performance of a genotype is not the same under different agro-ecological conditions and stability analysis is the most important for the selection of crop varieties as well as for breeding programs (Ali et al., 2003).

Based on this study, a number of shallot lines showed specific adaptability to favorable and poor yielding environments, and considering the stability parameter of the deviation from regression, those shallot lines that gave high regression coefficient produced the highest mean yields showing that those found to be specifically adapted to high yielding environment were favored. Hence, screening both for specific and wide adaptability could be necessary under Kulumsa (highland) and under Melkassa (dry land) conditions. Many years of research on yield and quality of shallot of different varieties and populations have allowed the researchers to identify many varieties with different traits that determine the excellent adaptation of this plant to various climate and soil conditions in which shallots are known and appreciated in both hot and cold climates (Cohat et al., 2001; Tendaj, 2005; Raduica and Popescu, 2010; Awale et al., 2011; Van den Brink and Basuki, 2012).

From these consecutive studies, the best performing Srilankan line Vethalam was released for the lowland areas of Rift valley with local name ʻYerasʼ which is to mean ʻHerathʼ to memorize the Former Srilankan expatriate who initially introduced this line from his country to evaluate and grow under Ethiopian conditions.

The main advantage of this shallot line is that it flowers and produces viable seeds satisfactorily under local conditions without any vernalization of mother bulbs. Moreover, it produced high bulb yield with uniform bulb size under both highland and lowland conditions. Therefore, this would enable farmers to shift from cultivation of shallot from bulb to seed producing shallot and can help them to grow disease-free crop in new areas and reduce cost of production by half. Off-season cultivation under irrigation and small rainy season are also benefits for the newly released variety.

According to the study of Van den Brink and Basuki (2012), the introduction of true seed shallot could be an option to improve competiveness of Indonesian shallot production and the recently developed true seed shallot cultivar 'Sanren' highly improved productivity, earliness, and quality for the local market which has increased feasibility of true seed shallot production. Alfu et al. (2013) also indicated that there are many shallot cultivars cultivated in Indonesia with greatly varying seed production potential, morphological traits and yield in which such variation indicates that there are genetic variations for flowering, and resistance to pest and disease. Moreover, Tendaj and Mysiak (2013) also in their study concluded that the production of shallots for commercial purposes was limited due to low supply of the seeding material as well as no breeding cultivars that would produce seeds and the local shallot populations commonly grown in various parts of different countries are reproduced mainly in vegetative way because they usually do not produce flower stalks nor seeds, or if they are formed, in a very reduced number and hence introducing and screening true seed shallots in different growing conditions for large scale commercial production should be the best option to benefit from this crop.

Conclusion

The combined mean yield range of the lines was 15.1–17.5 t ha^{-1} with mean average yield of 16.5 t ha^{-1}, in which Vethalam, Tropix, Dz-94 and Athlas gave the yield which was higher than the overall mean yield of 9 environments. The highest mean yield of 22.6 t/ha and 22.2 t ha^{-1} was recorded at Zewai during year 1 and year 3, which was considered the best yielding environment with high positive environmental index, followed by Melkassa in year 3 with yield potential of 18 t ha^{-1}. On the other hand, the environments of Kulumsa consistently produced low yield and were considered the poorest yielding environments. From the stability analysis, Vethalam and Athlas gave high yield in favorable environments. Vethalam was found widely adaptable line, whereas Tropix seemed a high yielder in low yielding environments, and was found unstable to changing environment. This study has confirmed the importance of stability parameters in identifying superior genotypes for potential areas in the Rift Valley of Ethiopia. Hence, it

suggested that initial selection of genotypes from any source at Kulumsa and Melkassa can produce cultivars that will be used across the diverse shallot growing environments in the country.

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OSOBINE LINIJA PRAVOG SEMENA VLAŠCA U RAZLIČITIM SREDINAMA ETIOPIJE

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R e z i m e

Sedam linija pravog semena vlašca su ocenjivane u toku tri godine na tri različite lokacije kako bi se odredile njihove osobine i stabilnost. Razlike u stabilnosti su ocenjene na osnovu linearne regresije linija preko ekološkog indeksa i devijacije od linearne funkcije zajedno sa srednjim prinosom. Kombinovana analiza je pokazala da se prinos lukovica u 9 sredina kretao od 15,1 do 17,5 t ha^{-1} sa ukupnim srednjim prinosom od 16,5 t ha^{-1}, a linije Vethalam, Tropix, Dz-94 i Athlas su dale najviši srednji prinos. Kombinovana analiza varijanse je pokazala značajan ($p<0,05$) uticaj genotipa i interakcije genotipa i sredine na prinos lukovica. Koeficijent regresije za prinos lukovica se kretao u rasponu od 0,72 do 1,36. Koeficijent regresije dve visokoprinosne linije (Vethalam i Athlas) je bio iznad 1 i bio je veći u sredinama gde su uslovi uzgajanja bili povoljni. Visoka i značajna devijacija je dobijena za linije Tropix i Athlas i one se smatraju nestabilnim pri promenama sredine. Međutim, linija Tropix je pokazala specifičnu adaptaciju na niskoprinosne sredine Kulumse i Melkase. Najbolja linija Vethalam sa malom devijacijom od regresije je bila u velikoj meri prilagodljiva različitim sredinama i plasirana je na tržište sa lokalnim imenom ʻYerasʼ kako bi se uzgajala u dolini Rift i sličnim oblastima u Etiopiji.

Ključne reči: vlašac, sredina, stabilnost, seme, prinos.

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