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RESEARCH ARTICLE

Agronomic Appraisal of Amaranth Accessions under Semiarid Conditions of Pakistan

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ABSTRACT

Grain amaranth is a high nutritive value crop and has high adaptability under wide range of climatic conditions. Thus, a field study was conducted for agronomic assessment of exotic grain amaranth accessions under Faisalabad conditions. The experiment comprised of eight accessions i.e., Ames-18027, Ames-18028, Ames-23317, PI-337611, PI-477915, PI-47916, PI-480625 and PI-480663. The experiment was conducted at Agronomic Research Area, Department of Agronomy, University of Agriculture Faisalabad, during spring season in 2013. The results revealed that maximum emergence count (93.33%), maximum time to panicle emergence (48.33 days), flowering (69.33days), milking (115.67 days) and maturity (130.67) were found in PI-480625, while, minimum values of these parameters were recorded in Ames-23317. Moreover, Ames-18027, also performed better in terms of growth, and recorded maximum branches per panicle (24) tallest panicle (34.33 cm), highest grain (1659.8 kg ha^{-1}) and biological yield (14971 kg ha^{-1}) than the rest of accessions. In conclusion, Ames-18027, PI-337611 performed significant better in terms of growth and economic yield under semiarid conditions of Faisalabad, Pakistan.

INTRODUCTION

Water scarcity becomes more threatening due to inconsistent and variable rainfall, global warming and climate change (Toung et al., 2005). Almost 5% water shortage as compared to average water use has been faced during 2014-15 with an acute water scarcity of 9.1% for crops during rabi season (winter) (GOP, 2015). In Pakistan total area under cultivation is 23 m ha out of which nearly 4.95 ha are the semi-arid (GOP, 2015). Moreover, the water resources are continuous depleting globally and in Pakistan. Under such problematic conditions, reliance on a few and highly input requiring crops with susceptibility to biotic and abiotic stresses brings in the high-risk factor. Failure of any crop in such a highly dependent cropping system leads to drastic loss in the economic balance of the country (GOP, 2015).

Introduction of new crops and testing of exotic germplasm for adaptation in the local environments is a potent option being utilized in the past for food security of the local folk. Similarly, crops with high potential to fit in a new environment and give comparative yields for widening the food options is an important avenue to overcome challenges due to mono-cropping and choosy crop husbandry (Gootjes et al., 1997). Water scarcity, considerably hinders crop husbandry as well as food security of the country. Such crops are needed not only to avoid failure but also to produce sufficient grain for the dietary needs in unfavorable conditions.

Amaranth is a grain crop of Central and South Americas with appreciable nutritive significance. It has high protein (14.5%) and lysine (6.2 g per 100 g protein) contents (Downton, 1973). Grain amaranth has been successfully grown in different countries with contrasting environmental conditions. These include

Australia (Angus et al., 1982), Argentina (Peiretti and Gesumaria, 1998), Germany and Poland (Kaul et al., 1996), China (Wu et al., 2000), Mexico (Espitia, 1992), Bolivia (Apaza-Gutierrez et al., 2002), Thailand (Senthong et al., 1992), India (Joshi, 1985) and Kenya (Gupta and Thimba, 1992) and USA (Sooby et al., 2005).

Grain amaranth is well-known for adaptability to a wide range of environmental conditions (NAS, 1984). A number of commercial products can be made from grain amaranth including snacks, bars, breakfast cereals, breads and pasta (Hackman and Myers, 2003). Grain amaranth can be a healthy food due to high protein contents and gluten free nature. It can be a good substitute for the people suffering from celiac diseases (Petr et al., 2003). Presence of essential amino acids especially lysine proves this grain as the best substitute to other diets especially in the poor and malnutrition regions of the world (Petr et al., 2003). Therefore, assessment of production potential of grain amaranth under local environment of Faisalabad can help this crop to be assessed for possible local acclimatization, keeping in view the nutritional status of the common folk. Proposed study was planned to address the phenological response, growth and yield potential of spring planted exotic grain amaranth spp. (*Amaranthus hypochondriacus*).

MATERIALS AND METHODS

The planned study was conducted during the spring, season of 2013 at Research area, Directorate of Farms University of Agriculture Faisalabad, Pakistan. The experimental site falls under semi-arid region, furthermore, prevailing climatic conditions during the crop growth season are presented in Table 1. Amaranthus accessions used in the study were imported from United States Department of Agriculture (USDA). Composite soil samples were obtained from the site, in order to determine the soil physical and chemical properties. Collected samples were analyzed by using the procedure advised by Homer and Pratt (1961). The soil was sandy loam having pH 8, Ec 1.72 dS m^{-1}, organic matter 0.67%, available nitrogen, phosphorus and potash 0.03%, 19 ppm and 119 pmm respectively.

Table 1: Prevailing climatic conditions of the experimental site during crop growing seasons for the year 2013

Months	Monthly mean max. temp (°C)	Monthly mean min. temp (°C)	Monthly avg. temp (°C)	Rainfall (mm)	Relative humidity (%)
March-13	27.0	13.0	20.0	61.2	1.3
April-13	33.5	19.7	26.6	36.7	21.6
May-13	39.7	24.4	32.0	24.5	4.6
June-13	39.5	27.9	33.7	43.3	67.5

A pre-soaking irrigation was applied before the seedbed preparation. The soil was ploughed thrice with cultivator followed by planking. Seeds were manually sown by keeping row to row spacing of 75 cm and plant to plant distance of 30 cm on ridges with the seed rate of 25 kg ha^{-1}. Nitrogen (N), phosphorus (P) and potassium (K) were applied at the rate of 45:67:50 kg ha^{-1}. N, P and K were applied in the form of urea (46% N), single super phosphate (14% P) and sulphate of potash (50% K). Full dose of P and K and half dose of N ware applied at time of sowing and remaining nitrogen were applied in two splits. Three irrigations were applied till maturity, 1st was at multiple leaves stage, 2nd was at panicle emergence and 3rd was at milk stage. All the other agronomic practices were kept normal and uniform for all the treatments. Necessary plant protection measures were adopted to keep crop free from weeds, insects and diseases.

Field was visited daily in afternoon to study the phonological stages of amaranth. Final emergence percentage was determined when maximum and healthy plants were established. Ten plants from each plot were selected at random and tagged in order to determine the time to bud formation, panicle emergence and flowering, milking and maturity. Leaf area was measured with the help of leaf area meter (CI-202, CID Bio-Science); and the leaf area index (LAI) was calculated by using a standard formula described by Watson, 1947. At harvesting ten plants from each plot were selected to determine the plant height, number of leaves per plant, number of branches and panicle length, and later on average was taken. The whole plots were harvested and dried to determine the biological yield and latter on manually trashed and grain yield was determined. The per plot biological and economic yield was converted mathematically into kg ha^{-1}. Harvest index (HI) was calculated by the following the formula: HI= grain yield/ biological yield × 100.

The experiment was laid out in randomized complete block design with three replications. The net plot size was 3 m × 4.5 m. Data were statistically analyzed by Fisher's analysis of variance technique and the difference amongst treatments were computed by using least significant difference test at 5% probability (Steel et al., 1997).

RESULTS

The results indicated that accessions had differential response for germination and phenology (Fig. 1). The maximum emergence count (93.33%) was recorded in Ames-18027 that comparable with PI-337611 (93%), whereas the minimum emergence count (38%) was recorded in Ames-23317. Likewise maximum time to bud formation (34 days) and panicle emergence (48.33 days) was found in PI-480625, meanwhile, the minimum time to bud formation and panicle emergence was recorded in Ames-18027 (Fig. 1 b,c). Similarly, the maximum time to flowering (69.33days), milking (115.67 days) and maturity (130.67) was recorded for PI-480625, followed by PI-477916, while the minimum time to flowering, milking and maturity were recorded in Ames-18027 (Fig. 1 d, e, f).

The results indicated that accessions had differential response for the growth and yield attributes (Table 2). The maximum plant height (156 cm) was recorded in PI-337611 that was comparable with Ames-1802, PI-477915 and PI-480625 whereas the minimum plant height (52cm) was recorded in Ames-23317. Likewise, maximum number of leaves per plant (285) was obtained in PI-337611; however, it was at par with Ames-18027 (278). Meanwhile, the lowest numbers of leaves (54) were found in Ames-23317. The results revealed that maximum leaf area index (4.87) was

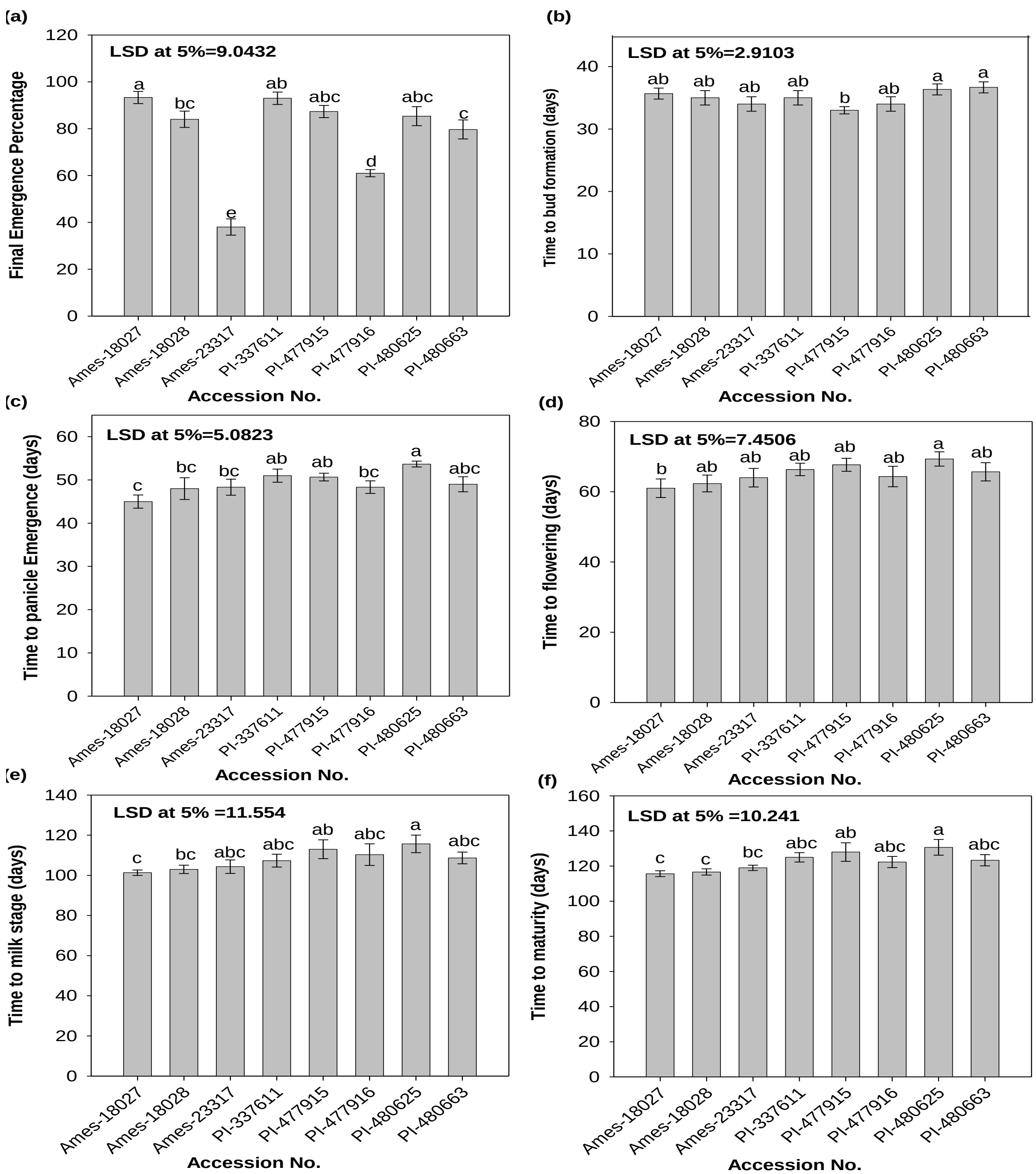

Fig. 1: Difference among amaranthus accession for (a) Final Emergence Percentage (b) Time to bud formation (days) (c) Time to panicle emergence (days) (d) Time to flowering (days) (e) Time to milk stage (days) and (f) Time to maturity (days).

Table 2: Comparison of amaranth accessions for growth and yield parameters

Accession No.	Plant height (cm)	Number of leaves per plant	Leaf area Index	Number of branches per plant	Panicle length (cm)	Biological yield (kg ha^{-1})	Economic yield (kg ha^{-1})	Harvest index
A_1:Ames-18027	155^{a}	278^{a}	3.77^{b}	23.67^{a}	34.33^{a}	14971^{a}	1659.8^{a}	0.110^{e}
A_2:Ames-18028	143^{ab}	199^{c}	3.30^{bc}	17.67^{bc}	29^{a-c}	11139^{b}	1350.3^{b}	0.121^{c}
A_3: Ames-23317	52^{d}	54^{f}	2.83^{c}	6.33^{d}	20.33^{d}	3511^{e}	316.9^{d}	0.090^{h}
A_4: PI-337611	156^{a}	285^{a}	4.87^{a}	24^{a}	34^{a}	11688^{b}	1665.8^{a}	0.142^{a}
A_5: PI-477915	151^{ab}	226^{b}	2.90^{c}	20^{ab}	31.33^{ab}	9748^{bc}	1294.8^{b}	0.132^{b}
A_6: PI-477916	87^{c}	91^{e}	2.70^{c}	9.67^{d}	24^{cd}	6882^{d}	676.3^{c}	0.098^{g}
A_7: PI-480625	147^{ab}	205.67^{bc}	3.43^{bc}	19.33^{b}	30.67^{a-c}	10405^{bc}	1216.3^{b}	0.116^{d}
A_8: PI-480663	137^{b}	151.33^{d}	3.33^{bc}	14.67^{c}	25^{b-d}	8499^{cd}	912.9^{c}	0.107^{f}
LSD ($P \leq 0.05$)	15.4	22.14	0.75	4.09	6.72	2117.2	241.56	0.0015

Means sharing the same letter for a single parameter do not differ significantly at $P \leq 0.05$.

obtained in PI-337611, followed by Ames-18027, moreover, minimum leaf area index (2.70) was found in PI-477916. Further, all the accessions had differential response toward the branches per plant and panicle length (Table 2). The maximum branches per plant (24) were recorded in PI 337611, however, it was same with Ames-18027 and PI-477915, while the minimum branches per plant (6.33) were recorded in Ames-23317. Further, maximum panicles length (34.33 cm) was observed in Ames-18027 and minimum panicle length (20.33 cm) was recorded in Ames-23317 (Table 2).

The tested accessions also had considerable variations in terms of biological yield, grain yield and harvest index (Table 2). Accession PI-337611 produced maximum biological yield 1665.8 kg ha $^{-1}$, followed by Ames-18027, whereas the Ames-23317 produced lowest biological yield 316.9 kg ha $^{-1}$ (Table 2). Furthermore, the maximum grain yield (1665.8 kg ha^{-1}) was recorded for Ames-18027 that was at par with accession PI-337611 with the grain yield of 1659.8 kg ha^{-1}, meanwhile the minimum grain yield of 316.9 kg ha^{-1} was produced by Ames-23317. Similarly, maximum harvest index (0.142) was recorded in PI-337611 while the lowest harvest index (0.090) was recorded by Ames-23317.

DISCUSSION

Emergence count is the primary parameter that indicates the growth of crop plants. All the tested accession had considerable difference for emergence count. This difference in emergence count could be due genetic variation of accessions and their ability to cope climatic conditions especially temperature. Phenology is an important factor which determines crop growth period and helps to determine the growth behavior and final production of crop (Khan et al., 2012). Introduction of any crop into new environment may face different challenges to adopt in particular environment. So, in this regard phenology of crop is very much important to address that challenges. In our study, Amaranth accessions had significant difference for the time to bud formation, panicle emergence, flowering, milking and maturity. This difference could be due to genetic variations and climatic response of amaranth accessions. Similarly, Wu et al., (2000) observed differences in growth period between the species and genotypes; such differences were partially attributed to sensitivity to day length and similarity of climate between site of origin of genotypes and targeted area for crop production.

Plant height is an important growth parameter. Amaranth accessions had considerable difference for plant height. The difference in plant may be due to genetic makeup and ability of plants to perform under climatic conditions. These results are supported with previous findings of Aufhammer et al., (1995) and Spehar et al., (1998) they also found the considerable difference among cultivars for plant height. Amaranth accession also had variable response for leaves and branches per plant. PI-227611 registered maximum leaves as compared to rest of tested accessions. The maximum leaves in PI-227611 can be ascribed to their genetic potential. These results are in consistence with earlier findings of Kusaksiz, (2010) they found the considerable difference among the cultivars for the leaves per plant. Leaf area index justifies the growth as well as the economic yield of the crop. Different amaranth accession registered the significant difference for the leaf area index; this difference may be due to difference in leaves per plant, as the accession having the more leaves produced more leaf area as compared to accession have lower leaves. These results are in consistence with findings of Khan et al., (2012) and Hassan et al., (2018) they also found the significant difference amongst cultivars for the leaf area.

Amaranth accession recorded a marked difference for biological yield. Difference in biological yield among the accession could be due to difference in growth attributes e.g. leaf area, plant height, leaves per plant and response towards the environmental conditions. Similarly, Aufhammer et al., 1995 and Spehar et al., 1998 recorded a significant difference for biomass yield among the genotypes and they correlated this difference with genetic characters and climatic factors. Similarly, accession also had differential response towards the grain yield. The difference in grain yield among the cultivars could be due to variations in growth, panicle length, and efficiency to cope with climatic factors (Henderson et al., 1998). Moreover, a significant variation in harvest index was recorded among the tested accessions. Accession PI-337611 registered maximum harvest index and Ames-23317 produced minimum harvest index. This difference in harvest index can be due to the variations in grain and biological yield. These results are in consistence with previous findings of Aufhammer et al., (1995) and Spehar et al., (1998) they also found significant difference among cultivars for grain yield.

Conclusions

The tested accession differed significantly in terms of phenology, growth and grain yield. Accession Ames-18027 and PI-337611 performed significant better in terms of growth and economic yield under semiarid conditions of Faisalabad, Pakistan. Therefore, the Ames-18027, PI-337611, can be used in different regions of Pakistan for its adoptability testing.

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Authors' contributions

MUC, IK, MBC, conceived the idea, deigned the project. IA conducted the experiment. MUH, MN, NUK, MU and M.A.U.K helped in the preparation of manuscript and literature search. MK helped in statistical analysis. All authors read and approved the final manuscript.

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