

Variations of genotypes, seasons and genotype by season interactions for yield, yield components and agronomic traits in finger millet

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ABSTRACT: The socio-economic importance of finger millet is high for African and some Asian countries, and the crop has considerable potential in dryland farming systems of semi-arid and arid regions. The research was conducted to determine: (i) the magnitude and nature of the genotype by season interaction, and (ii) the response of genotypes to different seasons. Thirty-five finger millet accessions were evaluated in the dry season of 2010/11 and the rainy season of 2011 at the Field Crops Experiment Station, Khon Kaen University, Khon Kaen, Thailand. A randomized complete block design with 3 replications was used in this study. The combined analyses showed significant differences among seasons, genotypes and genotype by season interactions for yield per plant, 1000-seed weight, finger length, plant height and days to flowering. Season contributed to a large proportion of variations in yield per plant (53.09%) and was moderate for plant height (32.28%). However, variations due to genotype varied for 1000-seed weight (38.34%), finger length (64.78%), finger number (36.80%), finger width (50.84%), plant height (39.06%) and days to flowering (64.79%) while variations due to genotype by season interaction were moderate for plant yield (23.05%), finger number (29.98%) and finger width (27.83%).

Keywords: *Eleusine coracana*, germplasm evaluation, plant breeding, genotype by environment interaction.

Introduction

Finger millet was domesticated 5,000 years ago from its wild progenitor *E. coracana africana* (Dida et al., 2006), and it is believed to have originated from East Africa mainly Ethiopia. The crop belongs to the family Poaceae, subfamily Chloridoideae. The crop is a staple food crop of world poorest inhabitants and widely grown in Asia and Africa (Upadhyaya et al., 2010). Finger millet is known under several local names such as bird foot millet, coracana, African millet, and ragi (Panwar et al., 2010).

The crop is rich in protein (6-13%) and calcium (0.3-0.4%) (Panwar et al., 2010), and minerals (Bisht and Mukai, 2000), and it is, therefore, an ideal food crop for infants and

invalids (Vavidoo et al., 1998). Furthermore, iron content is exceptionally high and that helps to reduce malnutrition problem (Upadhyaya et al., 2007).

Finger millet is a hardy crop and it is generally grown in low rainfall areas, where other cereals are not productive (Misra et al., 2010). It is, thus, a crop of choice in the drought prone areas of the world (Upadhyaya et al., 2007). The crop has a wide range of geographic adaptations compared to most cereals except for rice, which is highly resistant to water logging (Upadhyaya et al., 2004). Precise global area under production is not known because this crop has often been mixed with other millets (Dida et al., 2008). The yield of finger millet is in the range of 4-5 t ha⁻¹, but yields vary greatly depending on the country

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and regions (Dida et al., 2008). Low yielding of the crop compared to other cereals hampers its potential utilization as farmers prefer higher yielding crops, and the cultivars with high yield and better adaptation to diverse environments are not available for cultivation (Misra et al., 2010). Development of cultivars with high yield potential is a must for finger millet in order to gain better competition with other cereals.

An ideal cultivar must maintain yield levels not only in the original environment but also in many other environments within its intended area of production (Monyo et al., 2003). To achieve this goal, a large number of breeding materials must be evaluated in multi-environment trials to assess the effect of genotype x environment interaction. Morakinyo and Ajibade (1998) found that variation in seasons was as important as that of years. Genotype by season (GxS) interaction was more important than genotype x location interaction, indicating the importance in evaluation of breeding lines in more seasons than more locations if resources are limited (Pereira et al., 2011). Analysis of genotype performance under field conditions is basic to understanding environmental effects on crop growth at various cropping seasons and ultimate performance of a cultivar (Agele 2006).

Despite the importance of finger millet in African and Asian communities, the research on the evaluation of finger millet accessions in multi-location trials is very limited especially under different seasons. It is not clear whether the crop can be produced off-season in sub-tropical and tropical regions. Therefore, this study was undertaken to determine (i) the magnitude and nature of the GxS interactions for yield, yield

components and agronomic traits of finger millet and (ii) the response of genotypes to different seasons.

Methodology

Plant materials and weather conditions

Thirty-five accessions of finger millet obtained from International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) were used in this study. The accessions represent the germplasm collected from wide range of varying countries in Africa and Asia.

The soil of the experimental site is sandy loam and the climate of the locality is tropical with high humidity levels, with annual rainfall of about 1200mm with maximum temperature of about 40°C in summer and 26°C in winter season (**Figure 1**).

Seasons were different for rainfall, maximum temperature, minimum temperature, solar radiation and humidity. Received rainfall throughout the dry season was only 13.5 mm, whereas higher rainfall of 1283.5 mm was recorded in the rainy season. Average solar radiation was lower during the dry season (182 W/m²) as compared to the rainy season (190 W/m²). This can be attributed to the day length during dry season, which have shorter and cooler days as compared to the rainy season. Average humidity was higher in rainy season (90%) as compared to the dry season (86%).

Mean maximum and minimum temperatures were in the range from 10°C-25°C during the dry season and 25°C-40°C during the rainy season. The hottest months were April and May and the cooler months were December and January in both growing seasons.

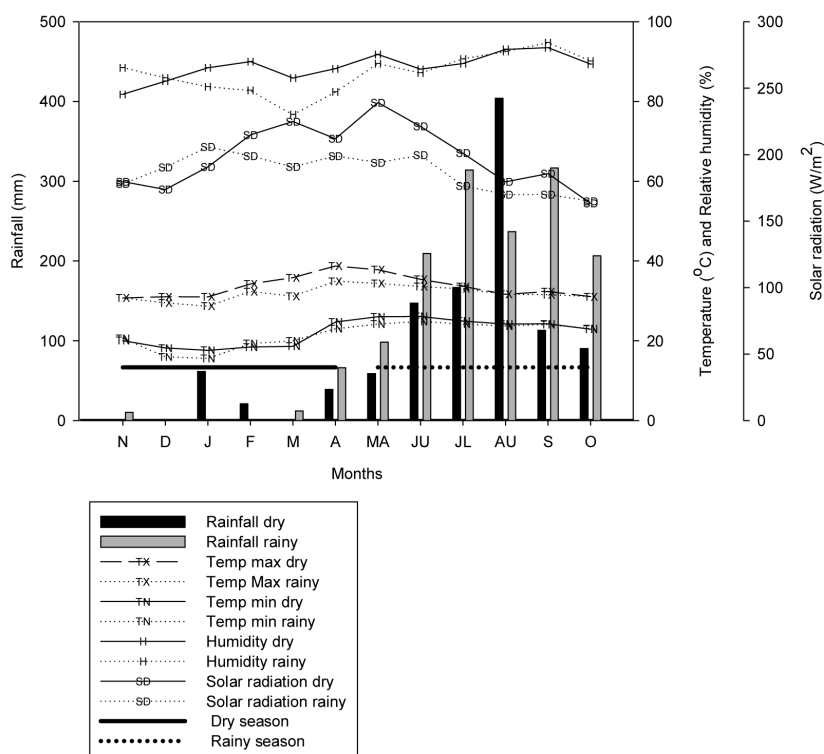


Figure 1 Weather data for the dry season 2010/2011 and the rainy season 2011

Experimental design and crop management

A field experiment was conducted for two consecutive seasons during November 2010 to May 2011 and June 2011 to October 2011 at the Field Crops Experiment Station of Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand (16° 30' N, 102° 47' E, 204 m asl). Thirty-five accessions of finger millet were arranged in a randomized complete block design (RCBD) with three replications.

The land was prepared by double plowing and leveling with a tractor, and flat plots of 1 x 5 m were made. Two splits of 15-15-15 fertilizer at the rate of 70 kg ha⁻¹ for each split were applied as basal dressing at sowing and top dressing at 40 days after emergence. Supplemental irrigation was supplied to the crop grown in the dry season

from planting day to soft dough seed stage.

Weed management was done twice at 40 days after emergence just before split fertilizer application and the second weeding was done at flowering. Wild pigeon is the most critical animal pest in the experiment. Therefore, nylon net was constructed to cover all plots in the experiment. Neither disease nor insect problem was observed during both planting seasons, and no chemical or natural control method was practiced.

Planting was done manually in the two-row plots with 5 m in length and spacing of 50 cm between rows and 20 cm between plants within rows, giving at total plant stand of 52 plants per plot. Two weeks after emergence, seedlings were thinned down to one seedling per hill.

Data collection

Data were recorded for yield, yield components and agronomic traits from five competitive plants in the middle of every plot. The traits recorded at harvest included yield per plant, 1000 seed weight of filled seeds, finger length (the longest finger in cm), number of productive fingers per panicle, finger width (thickness of the finger using a digital vernier caliper in mm), height (taken from the ground level to the tip of the tallest in finger in cm) and flowering (number of days from emergence to 50% flowering of tillers).

Data analysis

Combined analysis of variance was done for two seasons for yields, yield components and agronomic traits using MSTAT-C software. Means were compared by the least significant difference test (LSD) at 0.05 probability level, and correlation coefficient was also calculated to observe the relationships among yield, yield components and selected agronomic traits.

Results and discussion

Significant differences ($P < 0.01$) between seasons were observed for yield per plant, 1000-seed weight, finger length, plant height, finger width and days to flowering, whereas seasons did not significantly affect finger number and finger width (**Table 2**). The contributions of season to total variations were much higher than those of genotype and genotype by season interaction for yield per plant (53.09%). Higher contributions of genotype compared to those of season and genotype by season interaction were found for 1000 seed weight (38.31%), finger length (64.46%), finger number (36.80%), finger width (50.84%), plant height (39.06%) and days to flowering (64.79%). The contribution of genotype by season interactions was higher than that of genotype for yield per plant (23.05%) and higher than that of seasons for finger number (29.98%), finger width (27.83%) and days to flowering (22.92%).

Table 1 Eleusine coracana accessions and their countries of origin grown in dry and rainy season in 2010 and 2011 at Khon Kaen, Thailand

Accession	Origin	Accession	Origin	Accession	Origin
IE 501	India	IE 3470	India	IE 4734	India
IE 518	India	IE 3475	India	IE 4757	India
IE 1055	Unknown	IE 3614	Unknown	IE 4797	Maldives
IE 2034	India	IE 3618	India	IE 5066	Senegal
IE 2042	India	IE 3945	Uganda	IE 5201	India
IE 2043	India	IE 3952	Uganda	IE 5367	Kenya
IE 2217	India	IE 3973	Uganda	IE 5537	Nepal
IE 2430	Kenya	IE 4028	Uganda	IE 6059	Nepal
IE 2457	Kenya	IE 4121	Uganda	IE 6165	Nepal
IE 2872	Zambia	IE 4565	Zimbabwe	IE 7018	Kenya
IE 3077	India	IE 4671	India	IE 7079	Kenya
IE 3104	India	IE 4673	India		

Table 2 Analysis of variance with mean squares (% sum squares) for yield, yield components and agronomic characteristics of 35 finger millet accessions.

SOV	Df	1000 seed													
		Yield/plant		weight		Finger length		Finger no		Finger width		Height		Flowering	
		(g)		(g)		(cm)				(mm)		(cm)		(days)	
		MS	%SS	MS	%SS	MS	%SS	MS	%SS	MS	%SS	MS	%SS	MS	%SS
Seasons	1	106778**	53.09	18.18**	30.25	16.38**	16.38	2.52	0.42	2.78	0.84	26503**	32.28	2427.6**	9.29
Genotype	34	1216.3**	20.56	0.68**	38.31	1.89**	64.46	6.53**	36.80	4.89**	50.34	943.4**	39.06	498.2**	64.79
GxS	34	1363.2**	23.05	0.34**	19.25	0.40**	13.51	5.32**	29.98	2.70**	27.83	544.6**	22.55	176.2**	22.92
Error	136	42.6**	2.88	0.05**	11.37	0.04**	5.32	1.41**	31.86	0.45**	18.45	34.6**	5.74	5.6**	2.90
C.V.			12.91		7.72		6.58		16.18		6.40		5.91		2.96

*,**indicates significant at 0.05 and 0.01significance level respectively.

Yield per plant differences in seasons can be attributable to varying rainfall amounts between the two seasons, but the differences were not caused by difference in soil moisture because supplemental irrigation could supply sufficient water to dry season crop. Heavy rains during the rainy season could affect the flowering and seed set of finger millet. Yields of millet are greatly reduced if heavy rains are experienced during flowering and seed set stage of finger millet (de Wet, 2006).

However, season did not significantly affect finger number and finger width; these traits were affected mainly by genotypic differences. The other traits that genotypic difference contributed highly significant mean squares are 1000 seed weight, finger length, plant height and days to flowering. The results did not fully support the study of de Wet (2006), who concluded that finger millet is a photoperiod sensitive crop; with genotypic effect contributing 64.79% to the period taken to reach 50% flowering of evaluated accessions; it can be concluded that not all finger millet accessions are photoperiod sensitive.

The results indicate that yield and some yield associated traits are liable to environmental changes, even though some yield associated traits were more consistent. The traits showing consistent performance may be useful as selection criteria to improve yield. The traits which fluctuated with environmental changes also indicated that favorable environments are required for more full expression of these traits. In this study, dry season was more favorable for yield expression of finger millet, and it might be difficult to grow finger millet sustainably or profitably in the rainy season.

Highly significant interaction of genotypes by season shows that genotypes grown under two different seasons performed very differently for expression of character of interest. Sharathbabu et al. (2008) also found out that because of variations in weather conditions which prevailed during experimentations at three locations showed highly significant variance for almost all the traits studied signifying considerable differences among the environment and their predominant effects on characters.

Conclusion

The results of this study indicated that there was strong influence of seasonal changes on yield per plant. The genotype effect had strong influence on finger number, finger width, 1,000-seed weight, finger length, plant height and days to flowering. The dry season which had the lower rainfall amount and cooler temperatures in the experimental season resulted in better ecological conditions for finger millet production thus giving higher yields as compared to the rainy season. The results thus suggests that finger millet is best suited to be produced in low rainfall areas or be grown as an off-season crop in areas that receives high amounts of rainfall in the rainy seasons. High variability existed among finger millet accessions for almost all the traits under the study.

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