

COMPARATIVE PERFORMANCE OF MAIZE (*ZEA MAYS* L.) GENOTYPES ON PRODUCTIVITY, QUALITY, ROOT DYNAMICS AND PROFITABILITY IN NORTH EASTERN HIMALAYAN REGION OF INDIA

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Abstract

A field experiment on rainfed maize was conducted to evaluate the performance of 15 improved genotypes and compared with the popular local genotypes in terms of root morphology, productivity, grain quality and profitability. Results revealed that among the genotypes, hybrids-Vivek QPM-9 followed by Prakash recorded significantly ($p < 0.05$) higher leaf area and dry biomass led to the higher productivity (4860 - 5055 kg per hectare), which was more than two folds higher than the local genotype Chakhaochujak (hill) (2081 - 2113 kg per hectare). Root morphological characters like root length density and root surface area was recorded maximum in hybrids- DHM-117, HQPM-4, Vivek QPM-9 and Prakash than other genotypes including locals. However, grain quality parameters such as oil and starch contents were higher in local genotypes, but grain protein content was significantly ($p < 0.05$) higher in improved genotypes Pusa composite-3 (10.15%) followed by HQPM-4 (9.55%). Significantly ($p < 0.05$) higher production efficiency and profitability led to higher estimated net returns per hectare basis and benefit: cost ratios (by 2.39 - 2.44 times) in cultivation of hybrids (Vivek QPM-9 and Prakash) over local genotypes. Thus, exploring improved genotypes suitable to rainfed hilly ecosystem promises improvement of maize productivity *vis-à-vis* food and livelihood security in the NEHR of India and other similar agro-ecological regions of the world.

Introduction

Maize (*Zea mays* L.) is the third important cereal crop in the world after wheat and rice with respect to area and production. India is the fifth largest producer of maize in the world, contributing 3% of the global production, though productivity is much lower (2.4 metric tonnes per hectare) (DES 2014) than other potential maize growing countries like USA (10.18 metric tonnes per hectare), Argentina (7.00 metric tonnes per hectare) and China (6.33 metric tonnes per hectare) (FAOSTAT 2011). In the North Eastern Himalayan Region (NEHR), maize production plays a significant role in ensuring food security and is used both for direct consumption and as well as for second cycle produce in piggery and poultry farming. In NEHR of Manipur, area under maize cultivation is 19,440 ha with 2.29 metric tonnes per hectare (DES 2012 - 2013).

Among the several reasons for this low productivity, adoption of traditional low yielding genotypes susceptible to soil acidity induced fertility stresses (Patiram 2007) as well as erratic distribution of rainfall induced intermittent moisture stress in the rainfed upland condition (Choudhary *et al.* 2013) are some of the notable causes for low productivity in the region. In addition, small and fragmented land holdings, marginal farm mechanization due to high slope gradients across uplands and located sparsely, mostly away from settlements where connectivity is very poor causes hurdles in transportation of farm machinery and agricultural inputs. Adoption of marginal to almost negligible external inputs in the form of fertilizers and other agrochemicals often compounded the abiotic and biotic stresses in the rainfed uplands with acid soils and causes further reduction in productivity.

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Therefore, successful maize production depends on the correct choice of genotypes and application of production inputs to sustain the environment as well as agricultural production. Timely availability of location specific suitable genotypes can provide a major breakthrough in production and productivity. High yielding varieties (HYV) of maize widely adopted in other parts of country, but in the NEHR, most of the farmers are growing low yielding local varieties. The information on interaction of phenology of these HYVs and ambient temperature in maize performance under rainfed, acidic soils in the hilly ecosystem of NEHR is very important. It is anticipated that HYVs of maize with better management practices have immense potential to increase the existing production level by 2 - 3 times in the hilly ecosystem of NEHR. However, the suitability and performance of these genotypes under the agro-ecological condition of NEHR of India has not been evaluated yet.

Keeping these aspects in view, the present investigation was conducted with the hypothesis that the improved genotypes (HYVs) may give better grain yield and profitability without any penalty to the grain quality over the local genotypes in the agro-ecological condition of NEHR of India.

Materials and Methods

An experiment was conducted in coarse textured soil (sand content >55%) during May to September of 2012 and 2013 at Langol farm of ICAR Research Complex for NEH Region, Manipur Centre, Imphal, India. Experimental site falls under humid sub-tropical climate (24°49' N latitude, 93°55' E longitude and 780 m above MSL altitude). The daily minimum and maximum temperatures during the study period varies widely between 15.1 and 35.2°C in 2012 and 14.3 and 36.4°C in 2013, respectively (Fig. 1). During the experimental years, the site received an average annual rainfall of 1430.3 mm in 2012 and 818.7 mm in 2013, with high degree of monthly variations. The sunshine hours varies from 0.01 to 11.8 hrs in 2012 and 0.01 to 10.8 in 2013 while average relative humidity varied from 70 to 90%. The daily mean weather status of two years during the experimental period is presented in Fig. 1.

The soil of experimental site was loam in texture, acidic in reaction (pH 5.1), and high in organic carbon (Walkley and Black, 1.56%), medium in available nitrogen (alkaline permanganate N, 181.5 kg per hectare), low in available phosphorus (Bray I P, 9.1 kg per hectare) and available K (neutral normal ammonium acetate K, 60 kg per hectare).

Experiment was laid out in randomized block design with 17 maize genotypes and replicated thrice. There were two popular local genotypes of the region (Chakhaochujak-plain and Chakhaochujak- hill), two composites (Pusa composite-3 and Vijay composite) and 13 hybrids (HQPM-7, HQPM-5, BIO-9637, BIO-9681, PMH-1, HQPM-4, PMH-3, Vivek QPM-9, HM-8, PMH-4, HM-4, Prakash and DHM-117). The performance of these genotypes were tested and compared in the experimental field for two consecutive years (2012 and 2013). Maize was sown to the first week of May and harvested from late August to mid September. A common dose of nutrients (in terms of fertilizer applications) were applied: 100 kg nitrogen (N) per hectare, 60 kg phosphorus (P, in the form of P₂O₅) per hectare, and 40 kg potassium (K, in the form of K₂O) per hectare.

Leaf area was measured by passing the leaves through a LI-3100 leaf area meter (LiCor, Linoln, NE, USA), and then leaf area index (LAI) was determined on a ground area basis. The dry biomass was determined by uprooting 5 plants randomly from each plot at certain stages of crop growth. The plants were dried at 65 ± 1°C till the constant dry weight was achieved. For root morphology study, at kernel filling stage, three continuous plants of every treatment were selected. Root samples were collected using core sampler. The post harvest data on total biomass and grain

yield were recorded from the net plot area of $4.5 \text{ m}^2 \times 3.6 \text{ m}^2$ and grain yield of maize was reported at 14% moisture content. Similarly, stover of maize was sun dried and weight recorded as kg per hectare. Maize grain quality was estimated using near infrared spectroscopy (NIRS), with a FOSS grain analyzer (Infratec-1241) and software package IRIS 2.X (ISW 2.01) calibrated for this experiment against conventional wet laboratory analysis. Minimum support price (Fixed by Gov. of India) of maize in 2012-13 (INR Rs 11.75 per kg equivalent to US \$0.19; US \$ 1.0 is equivalent to INR Rs. 61.25) was considered for economics and BCR calculation.

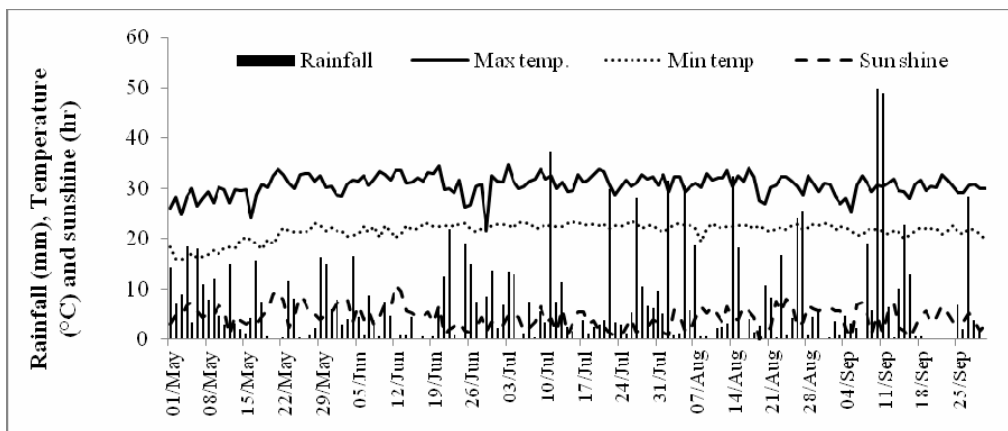


Fig. 1. Weekly mean weather parameter of two years (rainfall, maximum and minimum temperature, sunshine hour) at study area.

Two years mean data were presented. The data were subjected to analysis of variance (ANOVA) for 1-factor (seventeen genotypes) randomized block design (RBD) with Least Significant Difference test (LSD) at the 0.05 probability level for comparison of means of the treatment using PROC GLM SAS (SAS Institute, version 9.2).

Results and Discussion

Among the maize genotypes, leaf area index (LAI) and dry biomass at 30 DAS was recorded highest under Prakash and Vivek QPM-9, which was superseded by PMH-4 at 60 DAS and at maturity stages of the crop growth (Fig. 2A,B). The lowest LAI was obtained in Vijay composite and Chakhaochujak (plain). The highest numbers of cobs were recorded in Vivek QPM-9, Prakash, HM-4, Vijay composite and Chakhaochujak (hill) (Table 1). During both the years of experimentation, length and average girth of cobs were recorded significantly ($p < 0.05$) higher in Vivek QPM-9. The highest 1000-grain weight was recorded in HQPM-7 followed by BIO-9681. However, Chakhaochujak (hill) recorded the minimum length as well as average girth of cobs in both the years (Table 2).

Similarly, the various kind of maize genotypes also had significant ($p < 0.05$) effect on the grain yield. The cumulative effect of length of cob (24 to 29% higher than local), average girth of cob (on an average 31 to 39% higher than local) and 100 grain weight (24 to 34% higher than local) in Vivek QPM-9, Prakash and PMH-4 genotypes led to higher productivity. Grain yield varied from 2081.3 kg per hectare to as high as 5022.3 kg per hectare (Table 1). Our findings from the experiment depict that in acidic soils (5.1 pH) hybrid genotypes performed better than composite and local genotypes. However, genotypic performance varied from genotype to

genotype with the progress in crop growth stages from vegetative (0 - 30 DAS and 30 - 60 DAS) to reproductive stages of growth (60 DAS to maturity). The lowest maize grain yield was recorded in local genotypes (Chakhaochujak-hill and Chakhaochujak-plain). These findings are in line with those of Canavar *et al.* (2010). This might be due to genetic composition and suitability of the maize genotypes in this sub-tropical climate with acidic soils of Northeastern Himalayan Region (Pommel and Bonhomme 1998).

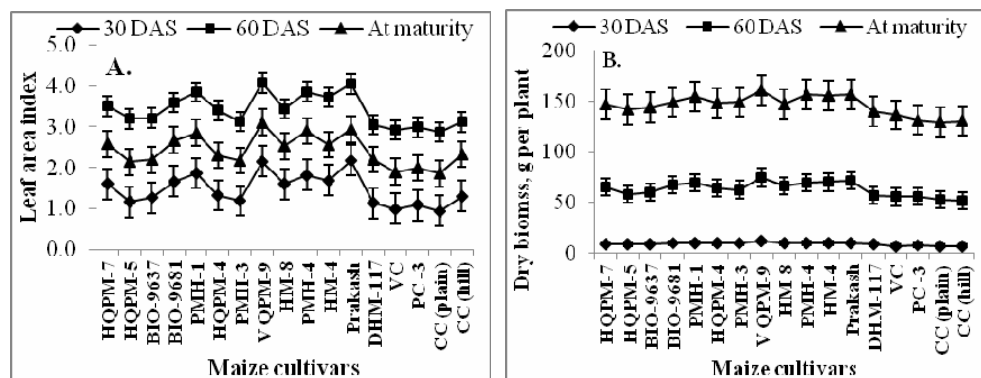


Fig. 2. Effect of maize genotypes on periodic leaf area index and dry biomass (mean of two years) at different growth stages (the bars are the standard deviations).

Table 1. Effects of genotype on yield attributes and yield of maize (mean of two years).

Cultivars*	Cob per plant	Length of cob (cm)	Av. girth of cob (cm)	100-grain weight (g)	Grain yield (kg per hectare)
HQPM-7	1.50	18.34	13.92	28.09	4012.5
HQPM-5	1.50	17.99	13.97	24.02	3282.6
BIO-9637	1.33	18.39	13.85	27.19	3456.1
BIO-9681	1.33	18.62	14.35	27.42	4057.6
PMH-1	1.67	19.77	14.96	23.78	4625.5
HQPM-4	1.50	18.28	14.69	22.71	3623.0
PMH-3	1.50	18.00	13.91	25.74	3143.1
*V QPM-9	2.17	21.07	16.95	27.97	5022.3
HM-8	1.50	19.27	14.32	25.32	3837.4
PMH-4	1.50	19.60	14.99	24.34	4787.8
HM-4	1.67	18.93	15.42	27.28	4319.9
Prakash	2.00	20.14	16.32	27.75	4866.3
DHM-117	1.33	17.90	13.80	25.42	2985.3
**VC	1.67	17.12	13.17	22.65	2753.9
^S PC-3	1.67	18.09	13.54	19.24	2847.9
[%] CC (plain)	2.00	16.24	11.59	21.50	2348.3
^{%%} CC (hill)	2.00	13.60	9.24	15.35	2081.3
LSD (p < 0.05)	0.80	0.33	1.14	0.84	175.8

*: *V QPM-9 = Vivek QPM-9; **VC = Vijay composite; ^SPC-3 = Pusa composite-3; [%]CC (plain) = Chakhaochujak (plain), ^{%%}CC (hill) = Chakhaochujak (hill).

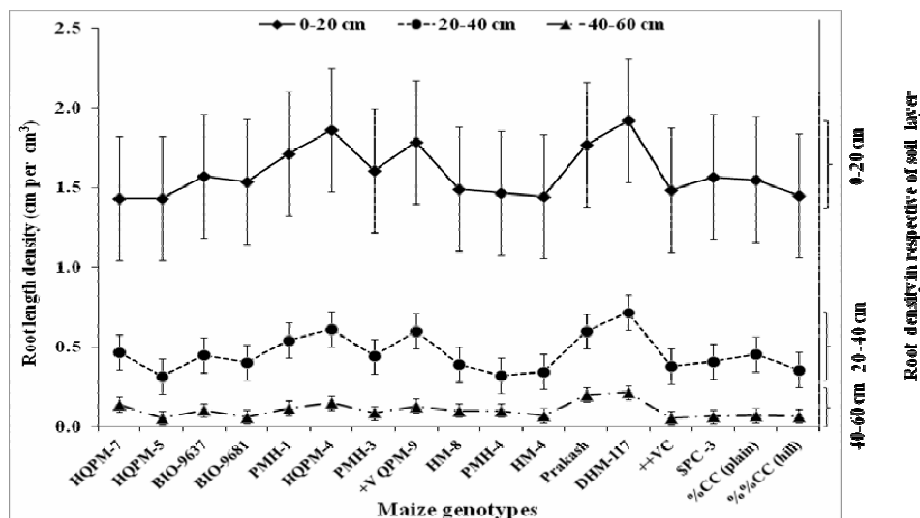


Fig. 3. Effect of genotypic variation of maize on root length density (mean of two years) at different soil depths (the bars are the standard deviations).

Irrespective of the genotypes, the maximum root length density (RLD) of maize was observed in the surface 0 - 20 cm soil layer and there was a significant decrease ($p < 0.05$) in the RLD along the depth (Fig. 3). The RLD showed significant ($p < 0.05$) variation among the genotypes in all the soil depths (0 - 20, 20 - 40 cm and 40 - 60 cm). Among the genotypes, maximum RLD in both surface (0 - 20 cm) and sub-surface (20 - 40 cm and 40 - 60 cm) layers were measured in DHM-117 followed by HQPM-4, Prakash and Vivek QPM-9 in both the years. Due to considerable variation in root morphology among the genotypes, RLD also reflected significant variation. Though, maize root can grow deeper, but more than 90% roots are distributed in the upper soil layer (Liu *et al.* 2010). The plough layer of hill soil differs from valley soils, particularly due to the presence of stones and pebbles. We have also observed that more than 75% of roots were confined in surface layer (0 - 20 cm) and with the increase in depth beyond 20 cm, root length density also decreased drastically across all genotypes. However, the distribution of roots in 0 - 40 cm soil layer reflected the rooting behaviour of different genotypes. The analysis of variance indicated that the effects of maize genotypes on root length density were significantly different ($p < 0.05$). Our findings also confirmed differences in morphological root characteristics of genotypes of different types (hybrid, QPM, composite and local). Variation in root length density among the genotypes was mostly due to the differences in root mass at various depths. The highest root length of maize genotypes was found in DHM-117 followed by HQPM-4 and Vivek QPM-9 at 0 - 20, 20 - 40 and 40 - 60 cm of soil depths, respectively (Fig. 3). The root lengths of the hybrids (QPM) were higher than the local genotypes. The average root length density of hybrids varied from 1.5 to 1.81 cm per cm³.

We observed substantial variations in maize grain quality across all genotypes. Among all the genotypes, grain oil content was significantly ($p < 0.05$) higher in local genotype Chakhaochujak (plain). Compared to hybrids (HQPM-7 and Vivek QPM-9), Chakhaochujak (plain) had 34% higher grain oil content while it was 75% higher over composites (Vijay composite) (Table 2). Vijay composite genotype recorded the lowest grain oil content ($< 4.0\%$) and was comparable to some of the hybrid genotypes (HM-8, PMH-3 and HQPM-5). Compared to Chakhaochujak (plain), other hybrid genotypes also recorded relatively less ($< 5.0\%$) grain oil contents during

both the years. The grain protein content was significantly ($p < 0.05$) higher in Pusa composite-3 (9.82 - 10.15%) followed by HM-4 (9.73 - 9.95%) and HQPM-4 (9.53 - 9.57%) (Table 2). However, grain protein contents were considerably low (7.1 - 7.3%) in Vijay composite, HM-8 and PMH-1. Compared to hybrids (HM-4 and PMH-1), local genotypes-Chakhaochujak (hill) and Chakhaochujak (plain) were considerably high (9.1 - 9.73%) in grain protein content. Similarly,

Table 2. Effect of genotypes on grain quality and economics of maize (mean of two years).

Cultivars*	Grain quality			Economics			
	Oil content (%)	Protein content (%)	Starch content (%)	Net returns (Rs/ha)	B : C ratio	CP (Rs/ha per day)	PE (kg/ha/day)
HQPM-7	4.66	7.61	71.87	30760.2	2.29	274.65	35.83
HQPM-5	3.76	7.51	73.57	20864.3	1.88	186.29	29.31
BIO-9637	4.16	8.76	72.25	23224.1	1.97	210.28	31.29
BIO-9681	4.20	7.63	72.33	31380.1	2.32	282.90	36.58
PMH-1	4.59	7.22	72.44	39237.6	2.64	350.34	41.30
HQPM-4	4.55	9.55	71.76	25433.8	2.07	223.11	31.78
PMH-3	3.84	8.80	72.15	18985.9	1.79	171.08	28.32
[†] V QPM-9	4.74	8.23	70.89	44638.8	2.87	404.01	45.46
HM-8	3.80	7.29	72.13	28435.6	2.19	258.51	34.89
PMH-4	4.17	7.79	72.16	41504.7	2.74	370.58	42.75
HM-4	4.05	9.84	71.83	35008.3	2.47	316.85	39.10
Prakash	4.27	9.10	71.51	42426.7	2.77	387.48	44.45
DHM-117	4.09	8.93	72.26	16852.9	1.71	155.36	27.53
⁺⁺ VC	3.62	7.12	73.46	16464.8	1.78	144.14	24.09
[§] PC -3	4.39	9.99	71.20	17855.3	1.85	157.73	25.14
[%] CC (plain)	6.31	9.14	70.91	10913.4	1.52	91.48	19.67
[%] CC (hill)	4.57	9.68	74.09	7285.4	1.35	60.99	17.42
LSD ($p < 0.05$)	0.26	0.41	1.73	2399.2	0.10	21.54	1.57

local genotype Chakhaochujak (hill) had the highest starch content followed by Vijay composite and HQPM-5. However, the lowest starch content was found in Chakhaochujak (plain), Vivek QPM-9 and Prakash (Table 2). Oil, protein and starch contents of maize grain across the genotypes, locals, composites and hybrids ranged from 3.60 - 6.3%, 7.12 - 9.9% and 70.9 - 74.10%, respectively. The observed variation in quality contents in grains might be due to genetic variation of genotypes since all the genotypes were grown under similar climate, soil and management practices. The local genotype Chakhaochujak (plain) was containing significantly ($p < 0.05$) more oil than the other genotypes. Significant influence of genotype on grain quality traits in maize was also observed by Melchinger *et al.* (1986). It indicates that the hybrids are suitable for cultivation in various locations subject to the conditions prevailing at the time of testing. Further, it is also useful in ranking of hybrids according to the grain quality (Ertiro *et al.* 2013).

Genotypic variation led significant ($p < 0.05$) differences in economics and profitability of maize cultivation (Table 2). During both the years, Vivek QPM-9 followed by Prakash and PMH-4 fetched higher net returns and thus, has higher B: C ratio than least performing local genotypes Chakhaochujak (hill), Chakhaochujak (plain), Vijay composite and Pusa composite-3. Vivek

QPM-9 recorded higher crop profitability (CP) and production efficiency (PE) as compared to other genotypes (Table 2). The lowest CP and PE was found in Chakhaochujak (hill) and Chakhaochujak (plain). Hybrid genotypes gave higher net returns and B: C ratio as compared to either of composite or of local genotypes, mostly due to more economic yield from the comparable cost of cultivation. Guan *et al.* (2007) also opined similar view of higher net return as well as food and nutritional security from the adoption of hybrids over local genotypes. Vivek QPM-9 followed by Prakash gave higher net and marginal returns than the other genotypes under our hilly sub-tropical Northeastern Himalayan Region. However, the PE of local genotypes was less by 145% as compared to the better performing hybrid genotype Vivek QPM-9. Less PE in hilly areas like our study area was mainly due to the adoption of low yielding local genotypes by farmers and not aware of better productive genotypes, suitable to the agro-ecological condition for their respective regions (Singh *et al.* 2014).

Cultivation of low yielding traditional genotypes of maize is one of the major reasons for low productivity (<1.50 tonnes per hectare) in the abiotic stressed rainfed terrace cultivated agriculture of NEHR of India. However, replacement of traditional genotypes by HYVs including hybrids will strongly depend on grain yield. Present investigation showed that selection of HYVs including hybrids with emphasis on better root morphological behaviour (root length density and surface area) with good management practices can improve the tolerance to moisture induced abiotic stresses experienced in NEHR and other similar agro-ecological region of the world. With moderate to high grain quality in terms of protein contents, higher net returns and B: C ratio from the comparable cost of cultivation may further increase the chance of adoption of improved over traditional genotypes among the farmers. Thus, adoption of promising genotypes can increase the profitability and production efficiency of maize *vis-à-vis* food and livelihood security of burgeoning population in the rainfed hilly ecosystem of NEHR of India and other similar rain-fed agro-ecological regions of the world.

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