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# Performance of different maturity groups of maize (*Zea mays*) hybrids under temporary waterlogging condition in a Mollisol

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ABSTRACT

Maize (*Zea mays* L.) genotypes of different maturity groups, i e extra early (EEM), early (EM), medium (MM) and late (LM) were evaluated under managed temporary waterlogging stress condition during the *kharif* season of 2010 and 2011. Data revealed that grain yield, yield attributes and physiological parameters remarkably varied with waterlogging stress among different maturity groups. The tolerance against waterlogging stress of EM and LM groups for plant stand resulted in higher average grain yield over other maturity groups. The mean grain yield of hybrids of different maturity groups differed significantly under normal and waterlogged conditions. Late maturity hybrid PMH-3 was to be the most tolerant against excess soil moisture stress (31.8 and 34.9% yield reduction) and medium maturity HM-9 was highly susceptible (55.2 and 64.6% yield reduction) during both years. Under temporary waterlogging condition, leaf diffusive resistance (LDR) and photosynthetic active radiation (PAR) showed positive correlation with grain yield while transpiration rate (TR) had negative correlation. Leaf temperature showed positive correlation ($r = 0.152$ and $0.323$) with PAR but negative with TR ($r = -0.447$ and $-0.122$). The findings indicated that late maturity maize hybrids followed by early maturity maize hybrids can be grown under excess soil moisture stress condition.

**Key words:** Hybrid, Maize, Waterlogging, Yield

Excess soil moisture stress caused by temporary waterlogging or poor drainage condition during heavy precipitation or high ground water table or heavy soil texture is one of the major environmental constraints for maize (*Zea mays* L.) production and productivity. In Asian region especially in south east Asia it suppresses maize growth and yield remarkably (Savita *et al.* 2004). In South East Asia alone, about 15% of the total maize growing area is affected by floods and waterlogging. Rice and some other crops can grow well under flooding conditions by supplying the required oxygen through internal aeration resulting from an increase in the air space of roots. But maize is known to be susceptible to the waterlogging if, it receives prolonged waterlogging during the monsoon or grown in poorly drained fields, although it develops adventitious roots and some morphological adaptations such as increased air spaces, i e arenchyma in nodal root tissues for its survival. The *kharif* season in India is characterised by the heavy and erratic rainfall, hence it is generally most difficult to avoid or drain out the stagnant water at one or other stages of the maize crop. Further low lying area also faces severe waterlogging problems during sowing. Waterlogging particularly early in the growth stage of the crop reduces the root growth, nutrient absorption and net assimilation hence causes greater crop yield losses (Lizaso and Ritchie 1997). The *tarai* belt of northern India has a wet season from mid June to September and heavy rains during this period result in waterlogging which is the main constraint to maize production in this specific region. The tolerance of maize genotypes towards this particular stress varies considerably and is highly influenced by the degree of stress and the genotype of the plant (Torbert *et al*. 1993). The effect of stagnant water on the maize crop has been studied enormously but on different maturity groups undertaken in little extent. Hence, there is a need of better understanding of response of the maize germplasm of different maturity groups under temporary waterlogging condition which have different tolerance and yield potential. Identification of morphological/physiological traits and incorporation of these traits in breeding programme is also important for the development of hybrids for excess soil moisture condition. This study was undertaken to evaluate the maize hybrids of different maturity groups for their response to waterlogging and to identify the different traits

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responsible for tolerance against waterlogging condition.

## MATERIALS AND METHODS

A field experiment was conducted at the N E Borlaug Crop Research Centre of GB Pant University of Agriculture and Technology, Pantnagar, Uttarakhand (29° N and 79.5° E, 243.8 m above msl) during the *kharif* season of 2010 and 2011. The centre falls in *tarai* belt of northern India lies below the foothills of Himalayas under humid subtropical climate with an average annual rainfall of 1 433 mm. Rainfall received during the maize growing period was above average at 1 872.4 and 1 989.7 mm in 2010 and 2011, respectively.The weather conditions during the crop season are shown in Fig 1.

The experimental soil was *Beni* silty clay loam up to 0.76 m depth followed by silt loam up to 1.50m depth. The soil water depletion data revealed that maize can utilize available water up to 1.2 m profile depth. Plant available water holding capacity up to this depth was between –0.03 and –1.5 Mpa potential and has been found to be 0.23 m. The soil has been classified as fine mixed hyperthermic *Aquic Hapludoll* (Deshpandey *et al.* 1971). The soil was neutral in reaction (pH 7.2), low in salt content (0.15 dS/m), medium in organic carbon (0.58%), available P (18.5 kg/ha) and available K (180.5 kg/ha).

A greater number of seeds of eight maize hybrids comprising two of each maturity groups, i e Vivek QPM 9 and Vivek hybrid 9 of extra early maturity (EEM), JH 3459 and Prakash of early maturity (EM), HM 8 and HM 9 of medium maturity (MM) and PMH 1 and PMH 3 of late maturity (LM) were sown on the leveled field at a depth of 5 cm on 16 June in both the years with a row length of 5 m by taking five rows at 60 cm distance. The plants were thinned after 15 days to maintain the equal distance between plants as well as uniform plant population to a density of around 83 000/ha. Based on soil test values, the plot was supplied 120, 60 and 40 kg N,$P_2O_5$ and $K_2O$ through urea, single superphosphate and muriate of potash, respectively, and 25 kg $ZnSO_4$/ha. Full dose of phosphorus, potash and zinc sulfate and one third of nitrogen was applied as basal at sowing time and remaining nitrogen was applied in two equal splits at 25 days after sowing (DAS) and tasseling stage as top dressing. Plant protection measures, weeding and hoeing were done as and when required.

To make the implementation of waterlogging easier, strong bunds of 30 cm base and 20 cm height were constructed around each plot in waterlogging treatments. In each plot (flood treatment), the soil was flooded with a water level of 5 cm above the soil surface at knee high stage (30 DAS) of crop and was maintained continuously for seven days. After seven days, ponding water was drained out through surface drainage. The knee high stage was used since according to results of Zaidi *et al.* (2004) maize is highly susceptible to waterlogging stress before reaching tasseling stage.

For the plant growth study, the three center rows excluding two plants closest to the alley at both ends of the row were used for data collection. Plant height, ear length, ear height and 100-grain weight were recorded from the five randomly selected plants. The height of the plants and ears was measured from soil surface to the top of the tassel and to base node of the cob, respectively, at dry silk stage. Days

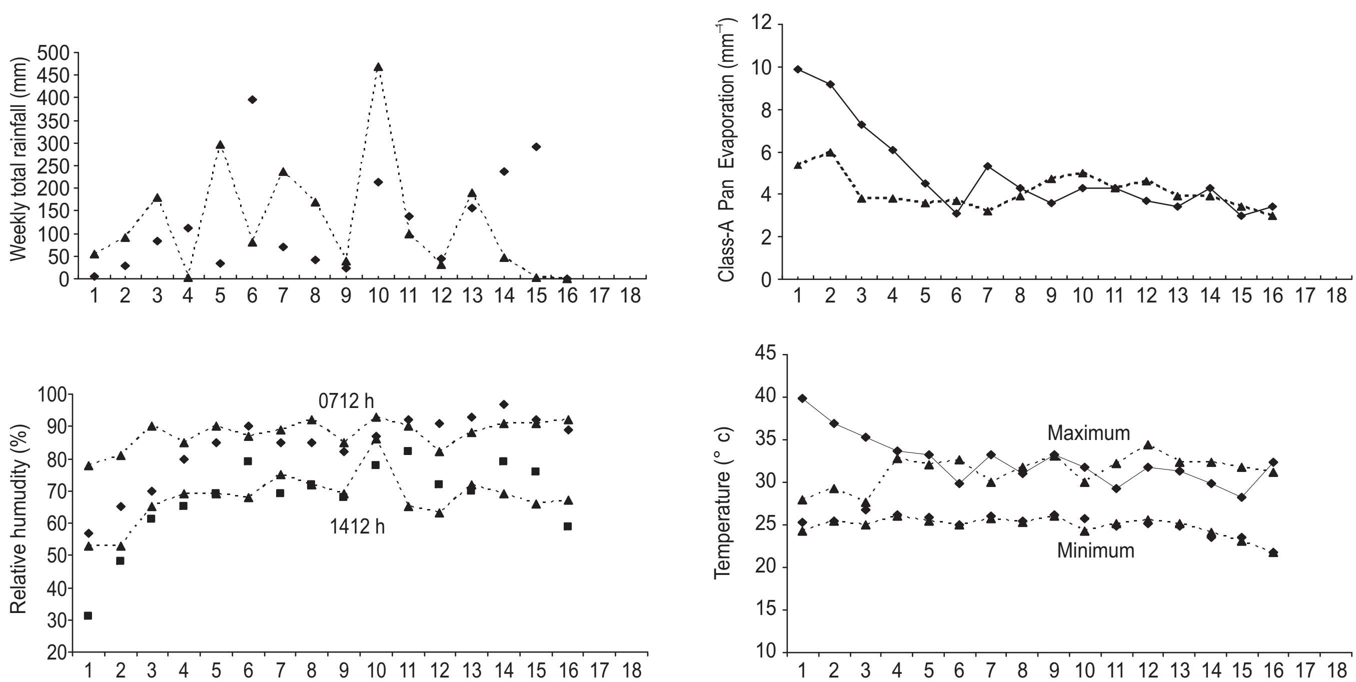


Fig 1 Weather parameters (weekly average) during maize growing period of 2010 (—◆—) and 2011 (--▲--).

from planting to anthesis and silking were estimated by regular observation up to the initiation of anthesis and emergence of silk in at least 50% of plants in each plot. Anthesis-silking interval (ASI) was calculated as the difference between the number of days to 50% silking and 50% anthesis. Mortality of plants in the waterlogged treatment was calculated by the difference of plant population just before the execution of ponding of water and after draining of water from the plot. Under waterlogged condition, few highly susceptible plants in some hybrids failed to reach silking, resulted in barren plants, were calculated as plant barrenness at maturity stage. Grain yield was recorded on a shelled grain basis and adjusted to 15% grain moisture.

## RESULTS AND DISCUSSION

*Effect of waterlogging on plant growth and yield*

The hybrids of different maturity groups selected for this study in general, had shown the significant variability in the growth and yield parameters in year 2010 and 2011 (Table 1). Plant stand varied from 73.6 to 83.3× $10^3$ /ha and 74.2 to 82.3× $10^3$ /ha under normal condition and from 43.4 to 77.1× $10^3$ /ha and 52.5 to 67.8 × $10^3$ /ha under waterlogged condition in 2010 and 2011, respectively. However, in general, average plant stand under waterlogging condition decreased by 22.80 % (from 79.39 to 61.31 × $10^3$ /ha) in 2010 and 24.12 % (from 79.21 to 60.13 × $10^3$ /ha) in 2011. Among different maturity hybrids, under waterlogged condition EM group in both the years in general, had maintained the superiority for plant stand over other maturity groups. However, EM (10.1%) and LM (22.5%) groups showed the highest average tolerance while MM (42.1%) and 29.2% (EM) were susceptible in 2010 and 2011, respectively. The tolerance against waterlogging stress of EM and LM groups for plant stand resulted in the highest average grain yield over other maturity groups. Increase in grain yield with increasing plant density was also reported by Husseyin *et al.* (2003)

Plant height among different maturity groups under normal condition varied significantly from 197.5 to 242.5 cm and 162.5 to 242.5 cm but under waterlogged condition from 142.5 to 215.0 cm and 125.0 to 210.0 cm during 2010 and 2011, respectively. Waterlogging reduced average plant height from 13.23 to 16.61% during both years. On the other hand, EM and MM groups exhibited maximum tolerance (10.1 and 20.6% reduction) while MM (38.8%) and EEM (30.3%) the highest susceptibility against waterlogging in 2010 and 2011, respectively, over other maturity groups. Similarly, average ear height decreased from 83.4 to 69.7 cm (16.4%) during 2010 and from 77.3 to 66.1 cm (14.5%) during 2011 on account of waterlogging. However, among different maturity groups, almost similar trend was noted as to that of plant height.

The 50% tassel and silk emergence were noticed significantly delayed owing to waterlogging in each maturity group but delay enhanced as the maturity period of hybrids increased. Average 50% tassel emergence delayed from 2.0 to 3.2 days (from 53.3 to 55.3 days during 2011 and 49.1 to 52.3 days during 2010) as well as 50% silk emergence by 2.7 to 3.7 days (from 57 to 59.7 days during 2011 and 52.9 to 56.6 days during 2010) in different hybrids. Among different maturity groups, delaying in average 50% tassel emergence was varied from 2.5 to 4.8 and 1.0 to 2.5 days and silking from 3.0 to 6.0 and 1.5 to 4.0 days during 2010 and 2011, respectively, where higher values was found with EEM group. In general, delaying was observed more in HM 9 and minimum in Prakash in both the years.

In general, Anthesis Silking Interval (ASI) got widened due to waterlogging. Extend in length of ASI resulted in poor pollination which in term affected the overall grain production (Lone and Warsi 2009). It varied significantly from 3.0 to 4.5 days and 4.0 to 5.0 days under normal and waterlogged conditions, respectively. Under waterlogging, the maize hybrids of MM group (HM 8 and HM 9) showed the highest ASI in both years over hybrids of other maturity groups. Hybrids QPM 9, Vivek hybrid 9, HM 8, PMH 1, JH 3459, PMH 3, and HM 9 had shown no difference in ASI during both years (Table 1). In MM group, Hybrids HM 8 attained the highest plant mortality of 36.6% during 2010 and EM, Prakash 34.6% during 2011. These hybrids followed similar trend for plant barrenness. Moreover, no mortality was observed in Vivek QPM 9, Vivek hybrid 9, JH 3459 and PMH 3 during both years.

With respect to the grain yield, the mean grain yield of hybrids of different maturity groups differed significantly under normal and waterlogged conditions (Table 1). The highest yields were recorded with hybrid PMH 3 under both conditions in both years while the lowest with HM 8 under normal and Vivek QPM 9 and HM 9 under waterlogged condition. On the other hand, the mean grain yield of hybrids in the normal environment was 5 033 and 5 552 kg/ha, and 3 004 and 2 633 kg/ha in the waterlogged condition which represents a reduction of 40.31 and 52.58%, during 2010 and 2011, respectively. It is noteworthy that the grain yields of all maturity hybrids were lower in the waterlogged than in the normal environment where waterlogging decreased grain yield by 19.3 to 55.2 % during 2010 and 34.9 to 64.6% during 2011, but the effect of waterlogging was found more pronounced (highly susceptible) with hybrid HM 9 during both years compared to other hybrids. However, among the maturity groups, EM and LM exhibited higher tolerance to waterlogging but MM was highly susceptible. The findings are in conformity with those of Savita *et al.* (2004) and Zaidi *et al.* (2010). The immense loss of grain yield under waterlogging might be due to the delaying of receptiveness of the style/stigma of the ear more than tasseling, which can contribute to a reduction in the number of grains/plant due to the loss of synchronism between the emission of the pollen grains and the receptivity of the style/stigma, which is

Table 1 Plant growth, yield parameters and grain yield of maize hybrids under normal (N) and waterlogged (W) condition

| Variety | Plant stand ('000 /ha) | | Plant height (cm) | | Ear height (cm) | | Days to 50% tasseling | | Days to 50% silking | | ASI (days) | | Mortality (%) | Plant barrenness (%) | Grain yield (kg/ha) | | Ear index (EI) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | W | N | W | N | W | N | W | N | W | N | W | W | W | N | W | N | W |
| *2010* | | | | | | | | | | | | | | | | | | |
| Vivek QPM 9 | 82.3 | 63.6 | 225.0 | 195.0 | 75.0 | 65.0 | 40.5 | 43.0 | 44.0 | 47.5 | 3.5 | 4.5 | 20.3 | 13.3 | 4504 | 1915 | 1.03 | 0.87 |
| Vivek Hybrid 9 | 83.3 | 66.6 | 230.0 | 215.0 | 80.0 | 65.0 | 40.5 | 42.5 | 44.0 | 47.0 | 3.5 | 4.5 | 20.0 | 9.3 | 4377 | 3351 | 1.00 | 0.91 |
| JH 3459 | 81.3 | 70.9 | 197.5 | 192.5 | 80.0 | 70.0 | 48.5 | 51.0 | 52.5 | 55.0 | 4.0 | 4.0 | 4.3 | 0.0 | 4812 | 3883 | 1.05 | 1.03 |
| Prakash | 83.3 | 77.1 | 215.0 | 195.0 | 82.5 | 75.0 | 47.5 | 51.0 | 51.5 | 55.0 | 4.0 | 4.0 | 3.8 | 2.7 | 5334 | 3774 | 1.00 | 0.97 |
| HM8 | 73.6 | 43.4 | 200.0 | 172.5 | 80.0 | 67.5 | 53.5 | 57.0 | 57.0 | 61.5 | 3.5 | 4.5 | 36.6 | 16.7 | 4214 | 2009 | 1.02 | 0.84 |
| HM9 | 74.0 | 46.9 | 210.0 | 177.5 | 85.0 | 70.0 | 51.5 | 57.5 | 55.0 | 62.5 | 3.5 | 5.0 | 27.9 | 3.0 | 5613 | 2515 | 1.03 | 0.97 |
| PMH 1 | 74.0 | 54.2 | 237.5 | 197.5 | 95.0 | 70.0 | 54.0 | 56.5 | 58.0 | 61.0 | 4.0 | 4.5 | 22.6 | 7.7 | 5580 | 2607 | 1.00 | 0.98 |
| PMH 3 | 83.3 | 67.8 | 242.5 | 210.0 | 90.0 | 75.0 | 57.0 | 59.5 | 61.0 | 63.5 | 4.0 | 4.0 | 6.6 | 0.0 | 5832 | 3975 | 0.97 | 0.97 |
| SEm± | 2.68 | 6.35 | 8.60 | 9.23 | 3.11 | 5.42 | 0.88 | 0.92 | 0.96 | 0.64 | 0.35 | 0.46 | 4.14 | 1.55 | 274 | 283 | 0.02 | 0.07 |
| CD (P = 0.05) | 8.97 | 21.22 | 28.74 | 30.85 | 10.41 | NS | 2.93 | 3.06 | 3.22 | 2.14 | NS | NS | 13.86 | 5.18 | 916 | 944 | NS | NS |
| *2011* | | | | | | | | | | | | | | | | | | |
| Vivek QPM 9 | 78.4 | 54.2 | 195.0 | 185.0 | 70.0 | 60.0 | 49.0 | 50.5 | 52.5 | 55.0 | 3.5 | 4.5 | 29.5 | 0.0 | 4540 | 1905 | 1.00 | 1.00 |
| Vivek Hybrid 9 | 80.3 | 56.5 | 202.5 | 185.0 | 75.0 | 62.5 | 48.0 | 51.5 | 52.0 | 56.0 | 4.0 | 4.5 | 28.4 | 0.0 | 5304 | 2725 | 1.04 | 1.00 |
| JH 3459 | 79.4 | 61.8 | 187.5 | 165.0 | 65.0 | 55.0 | 52.5 | 55.5 | 55.5 | 59.5 | 3.0 | 4.0 | 20.2 | 0.0 | 4465 | 2480 | 1.03 | 1.00 |
| Prakash | 82.3 | 62.5 | 195.0 | 175.0 | 72.5 | 65.0 | 54.0 | 55.0 | 58.0 | 59.5 | 4.0 | 4.5 | 34.6 | 19.5 | 3685 | 1840 | 0.97 | 0.75 |
| HM8 | 80.2 | 64.9 | 200.0 | 175.0 | 75.0 | 63.5 | 55.0 | 56.5 | 58.0 | 61.0 | 3.0 | 4.5 | 15.6 | 14.9 | 4445 | 1955 | 1.00 | 0.72 |
| HM9 | 74.2 | 57.9 | 205.0 | 177.5 | 77.5 | 65.0 | 56.5 | 57.0 | 60.0 | 62.0 | 3.5 | 5.0 | 28.8 | 10.3 | 5295 | 1875 | 1.04 | 0.84 |
| PMH 1 | 78.8 | 55.4 | 227.5 | 188.5 | 90.5 | 78.0 | 54.0 | 56.5 | 58.0 | 61.0 | 4.0 | 4.5 | 30.6 | 2.6 | 6285 | 3620 | 1.03 | 1.09 |
| PMH 3 | 80.1 | 67.8 | 232.5 | 203.5 | 92.5 | 80.0 | 57.0 | 59.5 | 61.0 | 63.5 | 4.0 | 4.0 | 14.5 | 5.4 | 6395 | 4165 | 0.88 | 1.05 |
| SEm± | 1.76 | 2.06 | 6.23 | 6.66 | 3.80 | 3.86 | 0.46 | 1.21 | 0.60 | 1.17 | 0.27 | 0.46 | 2.56 | 2.12 | 321 | 236 | 0.02 | 0.09 |
| CD (P = 0.05) | NS | 6.87 | 20.82 | 22.26 | 12.69 | 12.91 | 1.55 | 4.06 | 2.00 | 3.94 | NS | NS | 8.58 | 7.07 | 1075 | 788 | 0.08 | NS |

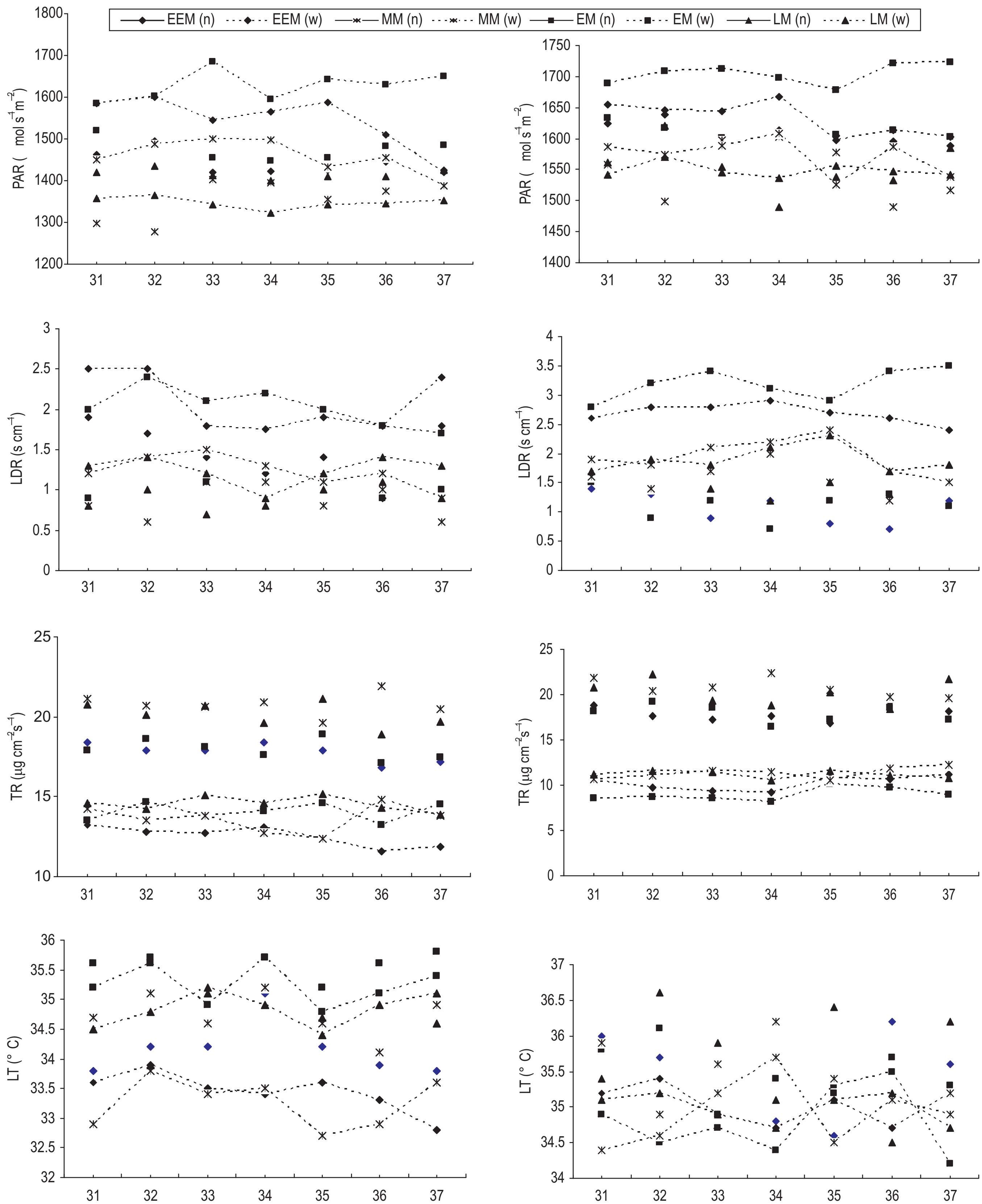


Fig 2 Variation in photosynthetic active radiation (PAR), leaf diffusive resistant (LDR), transpiration rate (TR) and leaf temperature (LT) in different maturity groups of maize hybrids during waterlogging period of 2010 and 2011.

Table 2 Correlation coefficients among different plant growth yield parameters and grain yield of maize hybrids under normal and waterlogged condition

| Parameters | Normal (N) | | | | | | Waterlogged (W) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Plant stand ('000/ha) | Plant height (cm) | Days to 50% tasseling | Days to 50% silking | ASI (days) | Grain yield (kg/ha) | Plant stand (000 ha) | Plant height (cm) | Days to 50% tasseling | Days 50% silking | ASI (days) | Mortality (%) | Plant barreness (%) | Grain yield (kg/ha) |
| *2010* | | | | | | | | | | | | | | |
| Plant stand ('000/ha.) | | 0.285 | –0.505 | –0.484 | 0.251 | –0.076 | | 0.680 | –0.451 | –0.492 | –0.784 | –0.927** | –0.530 | 0.764* |
| Plant height (cm) | | | 0.061 | 0.069 | 0.219 | 0.437 | | | –0.409 | –0.431 | –0.439 | –0.566 | –0.304 | 0.579 |
| Days to 50% tasseling | | | | 0.999** | 0.458 | 0.614 | | | | 0.999** | 0.015 | 0.130 | –0.311 | 0.069 |
| Days to 50% silking | | | | | 0.492 | 0.627 | | | | | 0.069 | 0.174 | –0.287 | 0.029 |
| ASI | | | | | | 0.603 | | | | | | 0.826* | 0.438 | –0.743* |
| Mortality (%) | | | | | | | | | | | | | 0.770* | –0.866** |
| Plant barreness (%) | | | | | | | | | | | | | | –0.823* |
| *2011* | | | | | | | | | | | | | | |
| Plant stand ('000/ha.) | | –0.071 | –0.216 | –0.184 | 0.239 | –0.307 | | –0.095 | 0.700 | 0.653 | –0.530 | –0.726* | 0.482 | 0.244 |
| Plant height (cm) | | | 0.470 | 0.549 | 0.591 | 0.904* | | | 0.230 | 0.215 | –0.178 | –0.169 | –0.237 | 0.749* |
| Days to 50% tasseling | | | | 0.991** | –0.049 | 0.274 | | | | 0.994** | –0.208 | –0.521 | 0.372 | 0.482 |
| Days to 50% silking | | | | | 0.086 | 0.335 | | | | | –0.101 | –0.466 | 0.416 | 0.429 |
| ASI | | | | | | 0.451 | | | | | | 0.578 | 0.340 | –0.522 |
| Mortality (%) | | | | | | | | | | | | | 0.075 | –0.361 |
| Plant barreness (%) | | | | | | | | | | | | | | –0.411 |

confirmed in the growth of ears without grains in the tips (Lizaso and Ritchie 1997).

*Effect of waterlogging on plant physiological parameters*

Waterlogging environment had a greater impact on most of the physiological traits except leaf temperature during both years (Table 2 and Fig 2). The mean values of photosynthetic active radiation (PAR) under normal condition varied from 1 353 to 1 513 and 1 506 to 1 613 μ mol/s/m$^2$ while in general, among hybrids it increased from 16 to 189 and 8 to 82 μ mol/s/m$^2$ during one week submergence varying from 1 336 to 1 652 and 1 536 to 1 735 μ mol/s/m$^2$ during 2010 and 2011, respectively. Early maturity group showed maximum increase in PAR values in both years. Waterlogging enhanced leaf diffusive resistance (LDR) by 1.3 to 2.0 times (0.3 to 1.0 s/cm during 2010) and 1.2 to 2.9 times (0.3 to 1.9 s/cm during 2011) as compared to normal condition. The values of LDR under waterlogging in general were less for susceptible hybrids (medium maturity group) than other one.

An increasing trend in transpiration rate (TR) was recorded as LDR increased. Similarly TR among various hybrids reduced by 4.8 to 6.3 and 1.1 to 7.6 μg/cm$^2$/s owing to waterlogging during 2010 and 2011, respectively. The susceptible hybrids HM 8 and HM 9 attained the higher TR compared to other hybrids, under both normal and waterlogged conditions during both years. Leaf temperature between hybrids was varied narrowly from 33.6 to 35.9°C and 33.1 to 35.2°C under normal and waterlogging situations, however, waterlogging slightly reduced LT in each hybrid.

During the seven days continuous submergence, none of the hybrid faced the critical limits for TR, LDR and LT as reported by Lal (1992) that the critical limits for TR were 4.10 to 4.52 μg/cm$^2$/s, LDR, 4.86 to 5.53 s/cm and LT, 37.8 to 39.3°C at wilting point in maize under waterlogging condition.

*Inter-character correlation between growth, yield and physiological parameters*

The inter character correlation calculated among the different growth and yield and physiological parameters under both environments in both the years are shown in Table 2 and 3. The growth and yield parameters are in general, positively correlated with grain yield under normal condition in both the years. While under waterlogged condition, ASI (–0.743*, –0.522), mortality (–0.866**, –0.361) and plant barrenness (–0.823*,-0.411) showed negative correlations with grain yield and plant population with mortality (–0.927**, –0.726*) in both the years. But 50% tassel emergence had highly significant and positive correlation with 50% silk emergence (0.999**, 0.991**) in both years.

Leaf diffusive resistance (LDR) showed positive and non-significant correlation (r =0.584 and 0.101) under normal condition while positive and significant correlation (r = 0.926** and 0.864**) under waterlogged conditions with PAR but negative correlation with TR during both the years.

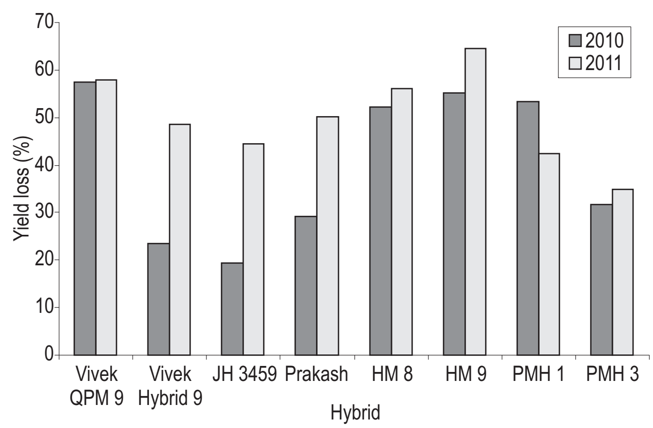


Fig 3 Yield loss (%) under waterlogged environment in different maturity maize hybrids during 2010 and 2011

Table 3 Correlation coefficients among different plant physiological parameters and grain yield of maize hybrids under normal and waterlogged condition

| Parameters | Normal (N) | | | | | Waterlogged (W) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | PAR (μ mol/ s/m$^2$) | LDR (s/cm) | TR (μg/ cm$^2$/s) | LT (°C) | Grain yield (kg/ha) | PAR (μ mol/ s/m$^2$) | LDR (s/cm) | TR (μg/ cm$^2$/s) | LT (°C) | Grain yield (kg/ha) |
| *2010* | | | | | | | | | | |
| PAR (μ mol/s/m$^2$) | | 0.584 | 0.476 | –0.058 | –0.217 | | 0.926** | –0.136 | 0.152 | 0.248 |
| LDR (s/cm) | | | –0.859** | 0.287 | 0.398 | | | –0.151 | 0.018 | 0.217 |
| TR (μg /cm$^2$/s) | | | | –0.112 | –0.281 | | | | –0.447 | –0.245 |
| LT (°C) | | | | | –0.542 | | | | | –0.823* |
| *2011* | | | | | | | | | | |
| PAR (μ mol/s/m$^2$) | | 0.101 | 0.446 | 0.303 | –0.402 | | 0.864** | 0.740 | 0.323 | 0.584 |
| LDR (s/cm) | | | –0.322 | 0.431 | –0.134 | | | –0.884** | –0.052 | 0.330 |
| TR (μg/cm$^2$/s) | | | | –0.207 | –0.436 | | | | –0.122 | –0.345 |
| LT (°C) | | | | | –0.368 | | | | | 0.420 |

Table 4 Mean values of seven days observation on plant physiological parameters of different maturity groups under normal and waterlogged condition

| Variety | PAR (μ mol /s/m$^{-2}$) | | LDR (s/cm) | | TR (μg/cm$^2$ /s) | | LT ($^0$C) | |
|---|---|---|---|---|---|---|---|---|
| | N | W | N | W | N | W | N | W |
| | | | | *2010* | | | | |
| Vivek QPM 9 | 1 513 | 1 529 | 1.6 | 2.1 | 17.6 | 12.5 | 33.6 | 33.1 |
| Vivek Hyb 9 | 1 372 | 1 561 | 1.4 | 1.9 | 18.1 | 13.4 | 34.5 | 34.0 |
| JH 3459 | 1 490 | 1 602 | 1.1 | 2.1 | 18.5 | 12.2 | 35.1 | 34.9 |
| Prakash | 1 465 | 1 652 | 1.2 | 2.1 | 17.6 | 11.4 | 35.9 | 35.6 |
| HM 8 | 1 353 | 1 437 | 0.7 | 1.2 | 21.2 | 15.9 | 34.2 | 33.7 |
| HM 9 | 1 358 | 1 481 | 0.8 | 1.3 | 20.4 | 15.6 | 35.2 | 33.9 |
| PMH 1 | 1 366 | 1 357 | 0.9 | 1.4 | 19.2 | 13.6 | 34.8 | 34.7 |
| PMH 3 | 1 464 | 1 336 | 0.9 | 1.5 | 21.2 | 14.7 | 34.6 | 34.9 |
| | | | | *2011* | | | | |
| Vivek QPM 9 | 1 649 | 1 657 | 1.2 | 2.5 | 14.5 | 9.4 | 35.4 | 34.8 |
| Vivek Hyb 9 | 1 569 | 1 607 | 1.0 | 2.9 | 16.0 | 9.5 | 35.5 | 35.1 |
| JH 3459 | 1 608 | 1 671 | 1.4 | 3.3 | 14.1 | 8.6 | 35.3 | 34.9 |
| Prakash | 1 613 | 1 735 | 1.9 | 3.2 | 16.8 | 9.2 | 35.7 | 34.9 |
| HM 8 | 1 525 | 1 582 | 1.3 | 2.0 | 15.3 | 12.8 | 34.9 | 35.1 |
| HM 9 | 1 573 | 1 561 | 1.4 | 1.9 | 13.5 | 12.4 | 35.2 | 34.8 |
| PMH 1 | 1 506 | 1 560 | 1.6 | 1.9 | 11.9 | 11.3 | 35.6 | 34.8 |
| PMH 3 | 1 604 | 1 536 | 1.5 | 2.0 | 15.9 | 10.9 | 35.8 | 35.2 |

Transpiration rate in general, showed positive and non-significant correlation with PAR and with grain yield it was negatively and non-significantly correlated. It was observed that the correlation among some others parameters were not accordingly due to the intermittent weather condition during the observation time.

The finding suggested that a considerable variation in general, in almost all parameters of different maturity maize hybrids groups was noticed under excess soil moisture condition, however, the adverse effect in terms of grain yield was more pronounced in medium maturity followed by extra early maturity hybrids as compared to other maturity hybrids. Among hybrids, PMH 3 was found to be the most tolerant against excess soil moisture stress condition. Moreover; late maturity hybrids (PMH 1 and PMH 3) had shown the highest yield potential and resistance over others under normal and waterlogged conditions. Leaf diffusive resistance was found higher in all hybrids under waterlogged condition hence reduced TR accordingly cause reduction in photosynthetic rate and productivity. Hence the late maturity maize hybrids followed by early maturity maize hybrids may be grown in the region where waterlogging is often occurred.

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