Original Research Article

Effect of Planting techniques, in maize (*Zea mays* L.) under excess soil moisture stress

ABSTRACT

Waterlogging is one of the major constraints limiting maize (*Zea mays* L.) production, especially in the Indian subcontinent. The objective of this investigation was to evaluate the efficacy of planting techniques by examining of physio-morphological, and productivity of excess water sensitive maize (Zea mays L.), under excess soil moisture stress (ESM). A field experiment was conducted during the *kharif* season 2020 at G.B. Pant University of Agriculture and Technology, Pantnagar. The experiment consisting of two planting methods (flat and ridge), under ponding conditions (30 DAS for 7 days) along with non-ponded condition was laid out in randomized block design with three replications. The recommended dose of nutrients was120:60:40kgN: P_2O_5:K_2O/ha. The physio-biochemical characteristics of the plants at different times after planting and the grain yield, crop lodging and plant height at harvest were evaluated. Growing of maize on ridge bed maintain comparatively aerobic condition and give better anchorage to sturdy in excess moisture resulting lowest crop lodging (12.06%) and higher yield (7.2%)) compare to flat system. In comparison to non-ponded and ponded plant showed significantly maximum growth, however lowest crop lodging percent.

Key word: Excess soil moisture, Zea mays, Ridge-flat, Ponded, Non-Ponded

1. INTRODUCTION

On global scale, floods account for almost two-thirds of all agricultural damage, costing billions of dollars (FAO, 2018). It is estimated that the areas subjected to waterlogging account for 12% of cultivating are as worldwide (Liu et al. 2017). In India, waterlogging is the second most serious alarming problem after drought to the third most important food crop next to rice and wheat in India. During 2018-19, the area covered by maize reached to 9.2 million ha (DAMNET, 2020). Maize is commonly considered prone to waterlogging, where soil moisture content reaches 80% of field capacity, maize growth and production would be seriously impaired in the Asian region (Mano et al. 2006; Ren et al. 2016). Waterlogging induced damages on plants depends upon genotype, the duration of waterlogging, stage of growth and soil temperature (Ren et al. 2016; Liu et al. 2016). It increases oxidative stress which damage cell internally and causes less carbohydrate accumulation resulting in extremely yield reduction (Srivastava and Gangey, 2007; Voesenek and Sashidharan, 2015).

Under waterlogged conditions, plants may suffer from nutrient deficiencies due to the excessive leaching of mobile nutrients specially nitrogen and increased denitrification (Steffens et al. 2005; Zaidi et al. 2007). The translocation of nitrogen is rapid and is metabolized by the leaves and stem under waterlogged conditions. So, by increasing the rate of nitrogen fertilizer plant adaptive mechanisms to waterlogging, such as adventitious root growth and root regrowth after flooding in maize can be enhanced (Nielson, 2015; Ren et al. 2017).

Ridging of soil is thought to be beneficial for better root development and for providing lodging resistance than that of flat planted maize (Thomas and Kaspar 1997). Better root architecture is known as one of the key factors for sound mechanical stability of growing plants (Potocka and Szmanowska-Pulka2018).

2. MATERIALS AND METHODS

2.1 Experimental location

The field experiment was conducted during *kharif* season 2020 at the Norman E. Borlaug Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, district U.S. Nagar (Uttarakhand), lies in *Tarai* plains which is about 30km southwards of foothills of Shivalik range of Himalayas at 29º N latitude, 79.5º E longitude and at an altitude of 243.84 meter above the sea level.

2.2 Treatment detail and Experimental design

The experiment was comprised of 2 planting methods viz., flat and ridge. Both treatments were subjected to waterlogging. One treatment i.e., flat sowing with recommended dose of nutrients without waterlogging was also carried as control.

The experiment was conducted in factorial Randomized block design with three replications. Artificial ponding was created at knee high stage (30 DAS). Depth of standing water was maintained 5 cm in the field continuously for 7days. The recommended dose of nutrients was 120 kg N, 60 Kg P_2O_5 and 40 kg K_2O per hectare. The NPK fertilizer (12:32:16: N: P_2O_5:K_2O), urea (46% N) and muriate of potash (60% K_2O) were applied as source of nutrients. Maize hybrid variety DKC-9144 released by “Bayer” company was used. Crop was sown on 17 July and harvested on 29 October, 2020. Seeds were sown in furrow and ridge manually by maintaining distance of 60 x 25 cm.

2.3 Soil and weather condition

The soil of *Tarai* region (Mollisols) has been developed from calcareous medium to moderately coarse textured parent material and poorly to moderately drained conditions. The climatic condition of experimental site experiences sub-tropical climate. The monsoon generally establishes during the second or third week of June and continues until the end of September. The meteorological parameters for the year 2020, namely minimum and maximum temperatures, and rainfall during the experimental period were recorded from meteorological observatory are depicted in fig.1.

2.4 Observations

2.4.1 Plant height

Five plants in each net plot were selected randomly and tagged. Height of these plants was measured with the help of meter scale at harvest stage.

2.4.2 Leaf area index

Three plants were selected from sample row in each plot i.e., second row from East. Plants were cut just above the soil surface with the help of sickle. All the leaves from each plant are removed and arranged into the groups viz. small, medium and large. Length and width of all leaves from each group were measured and average value was calculated. Leaf area of each category was calculated by multiplying their average length, width and correction factor (0.75) and at the end divide by spacing i.e. (60 cm ×25 cm). Average leaf area index per plant was calculated by dividing the value by three (Montgomery1911).

$$\text{LAI} = \frac{\text{Mean leaf Area}(\text{cm}^2)}{\text{Spacing}(60 \times 25)(\text{cm}^2)}$$

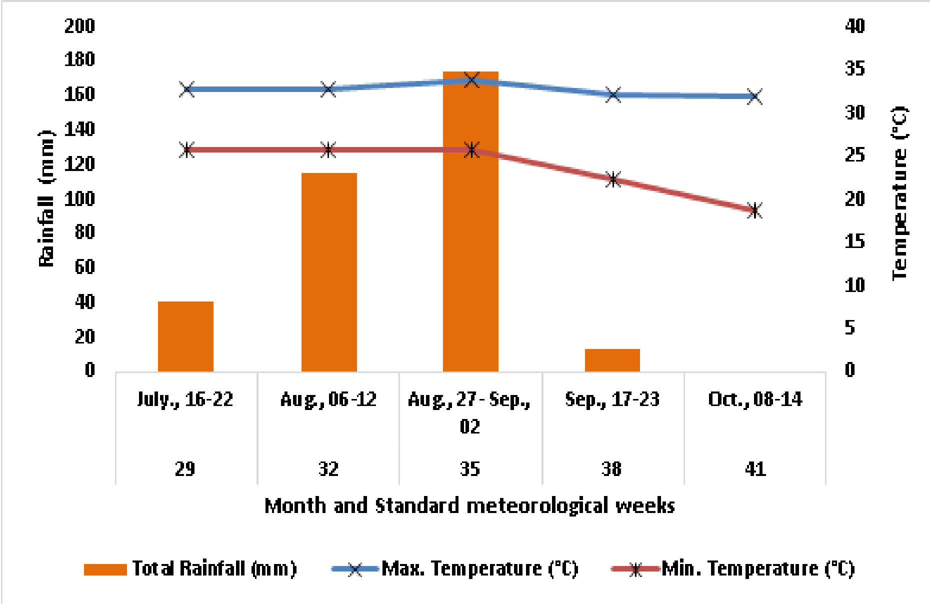

fig.1. Total rainfall, maximum and minimum temperature during crop growth in 2020.

2.4.3 Chlorophyll content

Chlorophyll content was assessed in fresh flag leaves at 1,14 and 28DACP by a method given by Hiscox and Israelstam (1979). It was extracted from 50 mg leaf discs with 10 mL Dimethyl Sulfoxide (DMSO) and kept in oven at 65◦C conditions for 3 h. The absorbance of the supernatant was measured at 646 and 663 nm using spectrophotometer.

$$\text{Total Chlorophyll} = \frac{[(20.2 \times A_{645}) + (8.02 \times A_{663}) \times V]}{\text{Weight (g)} \times 1000}$$

2.4.4 Plant lodging %

At harvesting plants which were lodged at angle more than 45 degree were counted in net plot area and lodging % was calculated by using following formula:

Plant lodging % $= \frac{No\ of\ plant\ lodged\ more\ than\ 45 degree\ in\ net\ plot}{Total\ no\ of plant\ in\ net\ plot} \times 100.$

2.4.5 Grain yield (kg/ha)

The cobs harvested from net area were harvested manually. After threshing, grains were collected separately for each net plot and their weight was recorded when grain moisture content was about 15%.

2.5 Statistical Analysis

The critical difference at 5% level of probability was calculated for testing the significance of difference between any two means wherever 'F' test was found significant (Gomez and Gomez,1984).

Thus, total 3 samples of farmers practice were compared with 3 samples of waterlogged maize grown with recommended dose of nitrogen in flat beds separately using 'student t' test as per method given by Rangaswamy (2006). Wherever, the calculated 't' value exceeded the tabulated value (2.776), the difference between the treatments was significant.

3. RESULTS and DISCUSSION

3.1 Growth Parameters

3.1.1 Plant height

In the present investigation as depicted in fig.4. the plant height under non ponded vs ponded, different planting techniques and in treatment combinations showed significant results at harvest. The non ponded condition attained significantly more height (232.2cm) as compared to ponded condition (129.8cm). The reduction in the plant height was to the tune of 44.1 % under ponding in flat beds condition.

3.1.2 Leaf area index

In the present investigation LAI varied significantly in ponded Vs non ponded, however nonsignificant in planting techniques which is depicted in fig.2. Plants grown under non ponded conditions showed significantly higher LAI (2.93 and 3.63) by 38.3% and 14.7% as compared to ponded condition (1.86 and 2.24) in flat beds at 14 and 28 DACP.

3.1.3 Total chlorophyll

The present investigation showed that total chlorophyll varied significantly in treatment combination and ponded Vs non ponded, but statistically similar in planting technique which is depicted in Table 1. The ESM condition quickly declined the total chl content (1.63, 1.65 and 1.95 mg/g FW) significantly in ponded grown were to the tune of (26.6%, 46.1% and 39.1%) reduction compared to non-ponded (2.2, 3.1 and 3.2 mg/g FW) in total chl at 1,14 and 28 DACP respectively.

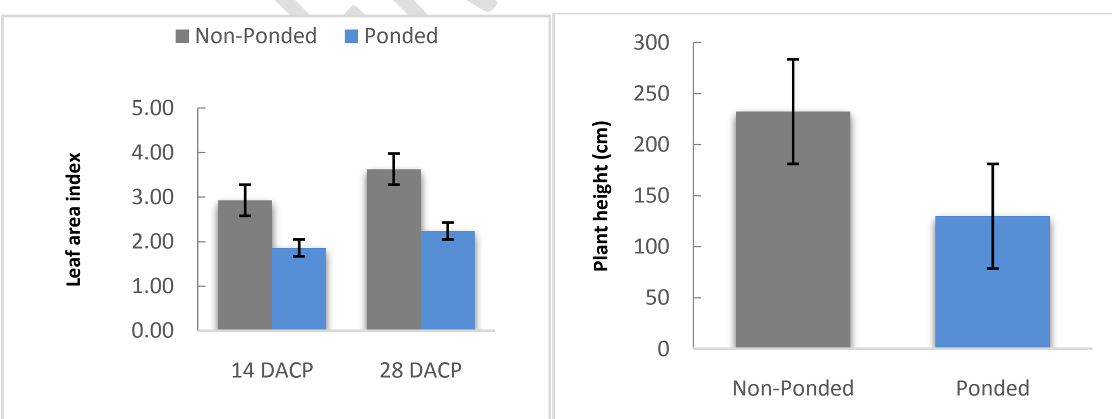

fig.2: Effect of ponded vs non ponding (*right side)* on plant height at harvest and leaf area index at 14 and 28 DACP.

3.1.4 Crop lodging per cent

The present investigation showed that at harvest crop lodging varied significantly in planting techniques as well as ponded vs non ponded condition, however, nonsignificant in treatment combination, which is depicted in Fig.3 The crop lodging % of plant grown under ridge planting system (12.06%) was significantly lower compare to flat planting system (16.8%).

3.1.5 Grain yield

In the present investigation as depicted in fig.4 the grain yield under non ponded vs ponded, different planting techniques showed significant results at harvest. As compared to flat planting system (3268 kg/ha), a relatively small increase (7.2%) in grain yield was found in ridge planting system (3501 kg/ha). The non-ponded condition acquired significantly higher grain yield (6506 kg/ha) as compared to ponded condition (1905 kg/ha).

Table 1. Effect of different planting systems, on chlorophyll content at 1,14 and 28 days after completion of ponding (DACP) in maize

Treatments	Total chlorophyll (mg/g FW)		
	1 DACP	14 DACP	28 DACP
Planting techniques			
Ridge	1.68	2.17	2.39
Flat	1.69	2.20	2.39
SEm±	0.02	0.01	0.01
CD (0.05)	NS	NS	NS
Non ponded vs Ponded			
Non-Ponded	2.22	3.06	3.20
Ponded	1.63	1.65	1.95
t value	6.78	35.77	47.55
Significance	*	*	*

NOTE: '*' means significant and NS means non-significant at 5%

Plant growth is a reflection of proper utilization of available growth factors by the crop particularly nutrients. LAI is used to reflect the eminence of plant nutrition and the potential capability of the leaf to photosynthesize (Gitelson et al. 2014). It is directly linked to the photosynthetic capacity that provides actual strength to the plants to process any physiological activity. The existence of excess water (water above field capacity) in the rhizosphere shows a negative impact on essential physiological activities such as cell elongation and cell growth rate were hampered resulting in stunted plant growth in maize (Ren et al. 2017).The present study showed that the plant growth (height and LAI) of *Kharif* maize was significantly decreased under ESM, due to nitrogen leaches through ammonia volatilization, NO_3^-, N leaching and denitrification of nitrate (NO_3^-) which may reduce plant growth. It could be reimbursed by increasing nitrogen fertilizer supply which alleviate the damages and can improve photosynthetic performance under ESM. Similar results were reported in field crop (Pan et al. 2015) and winter rape (Liu et al. 2017).

Crop lodging is an important factor which is negatively linked to grain yield of *Kharif* maize. In the present study, plants grown under ponding had significantly higher lodging %. This might be due to maximum nitrogen and other essential mineral are leached out in stagnant water, also blocking of various transporter which uptake of minerals, reduced third internodes width and bending property, the vascular bundle sheath thickness, stalk lateral breaking strength, the stalk cortex thickness, and vascular bundle number, resulting in promotion of per cent increase in crop lodging which is also agreed by (Duncan et al. 2018). Furthermore, the ridge techniques give more mechanical support, gives more rhizosphere and aeration, less prone to waterlogging, results in significantly less crop lodging per cent, which is also supported by Ren et al. (2013).

Our investigation reported that after ponding, quickly declined the total chl content resulted in leaf yellowing due to disorganization of photosynthetic apparatus under stress by excessive leaching of nitrogen, which is in accordance with earlier studies (Ashraf et al. 2012; Shah et al. 2012).

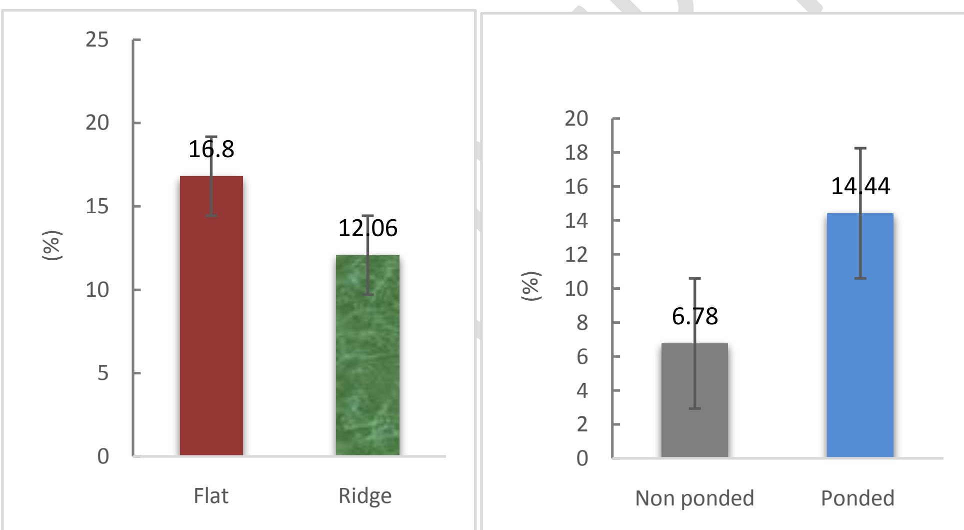

fig.3. Effect of planting techniques and ponding Vs non ponding condition on crop lodging at harvest

In the present investigation, the plants grown under ridge system had more yield advantage could be due to less sensitivity of ESM, creates loosening of soil gives better aeration zone thought to be beneficial for better root growth and architecture is the key factors for sound mechanical stability which resulted in to better growth of plant and improved yield attributes compare to flat planting system.

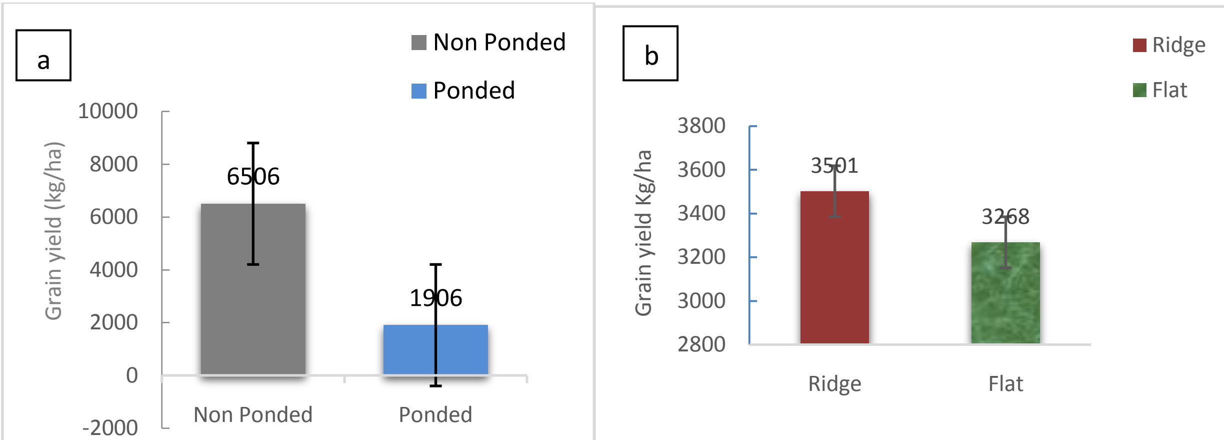

fig. 4. Effect of (a) ponded vs non ponding and (b) planting techniques on grain yield at harvest.

4.CONCLUSION

Thus, it could be concluded that, with respect to mitigate the yield penalty and crop lodging, ridge bed is also beneficial by giving better aeration in rhizosphere, to withstand in ESM.

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