Alleviating damage extent and enhancing yield through ridge planting techniquesin maize (*Zea mays* L.) during excess soil moisture stress

ABSTRACT

Waterlogging is one of the major constraints limiting maize (*Zea mays* L.) production in India and might become more common due to irregular precipitation pattern due to climate change. 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 factorial randomized block design with three replications. The recommended dose of nutrients was120:60:40kgN: P_2O_5:K_2O/ha. The physio-biochemical and yield characteristics of the plants at different times interval after planting 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 (3501kg/ha) by 7.2% compare to flat system (3268kg/ha). 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 damages 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 (Ren*et al.,* 2013). During the excess moisture condition, the planting soilin the furrow is evenly covered with ridge beds, and the planting soil is elevated3-4 cm above the flat soil, so, that the flat area between the ridge providing drainage runoff and alleviate water logged condition (Du *et al.,* 2021). In contrast to this,varied ridge and flat widths will change the plant population, growth and crop yield, and the physiology by which crop yield increases at varied ridge–flat ratios is not much clear (Zhang *et al.,* 2022).

In the wake of abruptly change in precipitation pattern, waterlogging is the concerning problem of maize in India. In line of this several research reports under various climatic conditions have stipulated the benefit of ridge planting techniques over traditional flat planting, such as reducing irrigation water use, reducing the seeding rate, andreducing crop lodging percentage, as well as higher levels yield of maize production with low operational costs (Devkota*et al.,* 2013). In contrast to this, a few research studies have used the planting techniques under excess soil moisture conditions to alleviate waterlogging. Therefore, it is imperative to study the mitigation approach of water logging at knee high stages by using different planting techniquesthat contribute to offset the yield reduction.The objective of the research reported here was to compare ridge planting with the widely used flat planting. In addition, losses due to water logging (ponding) conditionof maize cultivation and to identify whether ridge planting is arecommendedsolution for decreasing excess soil moisture stress and increasing yield production in flood prone area.

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 at29º 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 and 12 other combinations of N and gamma amino butyric acid (GABA) which is not mentioned in this article. All 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 angle

Leaf angle of 6th leaf counted from the lower side is reported with respect to horizontal line with the help of protector in degree (°).Three plants were selected from sample row in each plot and averagedto measure leaf angle.

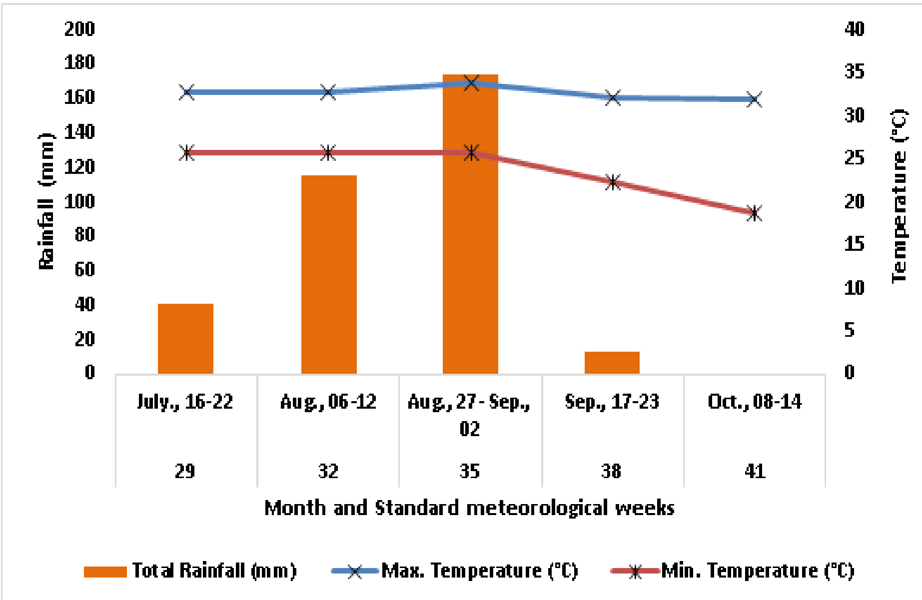

fig.1. Total rainfall, maximum and minimum temperature during crop growth in 2020.

2.4.3Chlorophyll 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:

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

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

Comparison of factor A (planting methods) and factor B (GABA and Nitrogen)was done as per procedure of factorial random block design using standard techniques of analysis of variance (ANOVA). 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.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

3.1Growth Parameters

3.1.1 Plant height

In the present investigation as depicted in fig.2. the plant height under non pondedvs ponded, different planting techniques and in treatment combinations showed significant results at harvest. The nonpondedcondition 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 angle

In the present investigation leaf angle varied significantly in ponded Vs non ponded as well as ridge vs flat planting techniques, which is depicted in table.1. At 1 and 14 DACP the plants grown under ridge planting system was nonsignificant andsignificantly wider angle (41.6°), respectively, as compared to flat planting system (39.4°) with respect to horizontal. Similarly, the plant of non-ponded conditions at 1 and 14 DACP, showed significantly higher leaf angle51.67° and 53.48°as compared to ponded condition 29.03° and 37.67°, respectively. The reduction in the leaf angle was to the tune of 39.2% and 29.5%, under ponding in flat beds.

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 2. 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 chlat 1,14 and 28 DACP respectively.

3.1.4 Crop lodging per cent.

The present investigation showed that at harvest croplodging varied significantly in planting techniques as well as ponded vs non ponded condition, however, nonsignificant in treatment combination, which is depicted in Fig.1 (a and b). The crop lodging % of plant grown under ridge planting system (12.06%) was significantly lower compare to flat planting system (16.8%).

Table 1: Effect of different planting systems, as well as ponded vs non ponded on plant height at harvest and leaf angle at 1 and14 days after completion of ponding (DACP) in maize

Planting Method	Plant Height (cm) at harvest	Leaf angle (°)	
		1 DACP	14 DACP
Flat	51.1	30.0	39.4
Ridge	50.8	33.9	41.7
SEm±	0.90	0.46	0.64
CD (0.05)	NS	1.35	1.87
Non-Ponded vs Ponded			
Non -Ponded	51.8	51.6	56.97
Ponded with RDN	52.1	29.03	37.6
t value	0.06	15.67	7.97
Significance	NS	Significant	Significant

3.1.5 Grain yield

In the present investigation as depicted in fig.2 (a and b)the grain yield under non pondedvs 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-pondedcondition acquired significantly higher grain yield (6506 kg/ha) as compared to ponded condition (1905 kg/ha).

Table 2. Effect of different planting systems, as well as ponded vs non ponded on chlorophyll contentat1,14 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. 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) of *Kharif* maize was significantly decreased under ESM, due tonitrogen 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 photosyntheticperformance under ESM. Similar results were reported in field crop (Pan*et al.,* 2015) and winter rape (Liu *et al.,* 2017).

Leaf angle is an important agronomic trait determining maize (*Zea mays*) planting density and light penetration into the canopy and contributes to the yield gain in modern maize hybrids (Wang *et al.,* 2022). In the current investigation, plant grown under ridge planting system has wider angle due to less physiological deficiency of water and also has better rhizosphere to growth of plant, which provide the alleviation of excess soil moisture.

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, which are leached out in stagnant water, also blocking of various transporter which leads to 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).

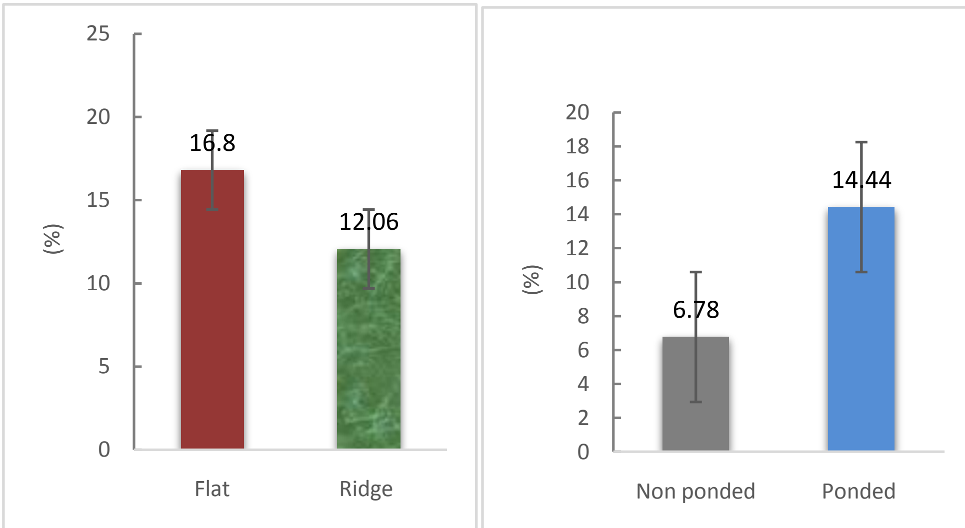

fig.1. Effect of planting techniques and ponding Vs non ponding condition on crop lodging at harvest

According to research reports, the planting pattern (ridge and furrow techniques) has been effectively alleviate stress during the maize production, which ultimately ensuring growth and grain yield (Gu*et al.,* 2019).Similarly, 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.

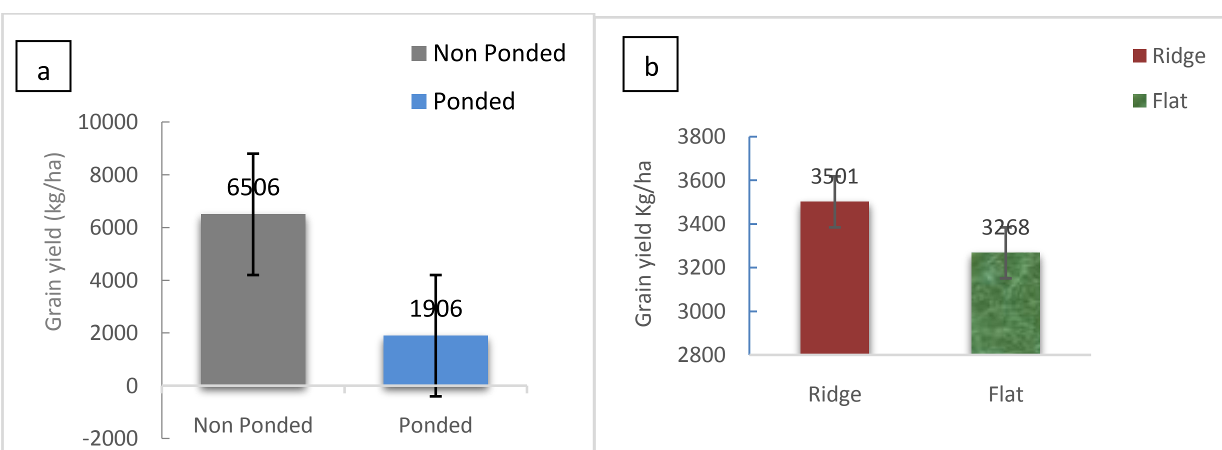

fig. 2. Effect of (a)ponded vs non pondingand (b) planting techniqueson grain yield at harvest.

4.CONCLUSION

In conclusion, the results of the present investigation inferred that during excess soil moisture stress in maize, creates significant damage in terms of growth, photosynthetic pigments, leaf angle, crop lodging and ultimately severe yield loss. These damages can be alleviated by using ridge planting pattern as a recommended solution, which enhance the damage extent to a limit range by increasing leaf angle, reducing crop lodging and ultimately increasing yield.

Declaration of conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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