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MAIZE GROWTH AND YIELD IN PESHAWAR UNDER CHANGING CLIMATE

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Abstract

Global climate change is consequence of accumulating greenhouse gases (Carbon) at lower atmosphere which might affects crops growth and yield. Maize is an important summer cereals, grown on considerable area in Pakistan every year. We, therefore, study the delay sowing response with changing climate on maize. Field experiment was conducted at Agronomy Research Farm, Agricultural University Peshawar, Pakistan in a randomized complete block design. Sowing was done from June 8 to July 24, 2010 with ten days intervals. Mazie (cv. Azam) was planted in rows at 0.75 m distance in NS orientations. Crop was raised under the uniform recommended cultural practices. Data regarding days to emergence, tasseling and maturity showed a consecutive decrease when sowing was delayed form June 08 onwards. However, the crop life cycle (i.e. vegetative and reproductive durations) initially remained uniform but expanded for late sowing dates (July). Delay sowing showed an increase in the leaf area index with an abrupt decline for the late sown crop. Nonetheless, plant stand at harvest remained static during the growth for all sowing dates. A stable to moderate reduction was noticed in ear length (cm) when sowings was delayed from Jun 08 onwards. Grain rows cob^{-1} did not influence by the delay sowing in the season. Moreover, delay sowing did not show any significant ($P<0.05$) change for the grain number. However, thousand grains weight was initially remained stable but declined ($P<0.05$) by delay in sowing. Biological yield, dry matter and grains yield ($g\ m^{-2}$) revealed almost a similar decreasing trend when sowing was delayed. Dry matter to grain yield relationship was linear ($r^2 = 0.95$) and revealed a mean loss of 1.65 $g\ m^2$ when sowing delayed from June 08 to July 24 in the season. Radiation use efficiency (RUE), the growth function, was also declined by the delay in sowing. We inferred that losses in leaf area indices, ear length and grain weights were basis of the grain yield reduction by changing climate of the growing season which brought a significant disturbance in the vegetative and reproductive phases of the crop life cycle that resulted losses ($P<0.05$) in grain yield by the late sown crop in the season.

Introduction

Global climate change is caused by accumulation of the greenhouse gases in the lower atmosphere. This has increased CO_2 concentration from 280 to 384 ppm in 2009 with a mean temperature rise of 0.76°C (DaMatta *et al*., 2010). It is also expected that by the end of this century, CO_2 will top 700 ppm or more with green house temperature rise by 1.8-4.0°C. The global concentration of gases is increasing day by day, mainly due to the human activities, such as combustion of fossil fuels that release CO_2 and deforestation which could cause removal of CO_2 from the atmosphere (Pastor & Post, 1988). It is estimated that global mean surface temperature may rise by 1.5-3.5°C and sea level by 15-95 cm by the year 2100. This may cause changes in the amount, time and duration of precipitation (Anderegg *et al*., 2010). The sea level rise also expected due to thermal expansion of oceans and melting of the mountain glaciers with temperature rise in future. The faster the climate changes, the greater would be the risk of damage to environment and its subsequent effect on crops. The recent assessments of climate change impact indicated that some regions are likely to be benefited from an increased in the agriculture productivity while others may suffer in reductions (Lioubimtseva & Henebry, 2009) including green fodder (Akmal *et al*. 2010). Crop production fluctuates with climate change in the different regions of the world differently (Wittmer *et al*., 2008). Early to late sowing affects crop growth and yield adversely due to changes in the climate of the area. However, these changes in the climate affect growth and subsequently the yield differently, depending upon the magnitude of change and developmental stage of the crop. The optimum sowing date of the crops and/or its validation is essential to sustain productivity under the climate change; particularly the high summer temperature effect on anthesis in circumstances in the area like Pakistan (Asim *et al*., 2013). A significant effect on growth and yield of maize has been already observed by changing climate of crop growth (Binder *et al*., 2008; Meza *et al*., 2008).

Optimum maize planting date is important with respect to regional climate change (Laux *et al*., 2010). It is between June 20 and July 15 in Peshawar, Pakistan (Akmal *et al*., 2010). Returns in the productivity by altering sowing dates of maize crop, particularly in the cooler area, have been described by Peter *et al*., (2009) in details but mostly with an adverse effect on yield in general due to high seasonal temperature on seed set, pollination and grain development including field soil moisture fluctuations (Lauer *et al*., 1999; Walker & Schulze, 2008). It has been established through research that planting date recommendations for an area shall be monitored through field experiments that have been done periodically with limited multiyear, multi-location with conclusions extrapolated statistically or otherwise. Nonetheless, planting date response depending on weather variability at a given location, also differ to a great deal among the years and locations etc. Knowledge of the planting window for any particular species and location is critical when selecting a variety for sowing when normal planting is delayed or for replanting when the plant stand is non-optimal following soil moisture losses or abrupt climate changes (Sun *et al*., 2007; Cirilo & Anrade, 1994).

Being major summer cereals crops of the region grown on the highest acreages, having improved varieties, production technology and its significant role in the cropping system, low average national production and its almost half in the Khyber Pakhtunkhwa province urges more efforts to explore reasons of the low productivity in the area (Asim *et al*., 2012) including nutrient management

(Arif *et al*., 2012). From many other reasons one reason could be rapid climate change during the vegetative growth (Meza *et al*., 2008). We therefore investigated yield and yield contributing traits response of maize with recent climate change by sowing maize early to late.

Materials and Methods

Field experiment was conducted at the Agronomy Research Farm of Agricultural University Peshawar during summer 2010. Sowing was done on different dates starting from June 08 to July 24 with ten days intervals. Experiment was conducted in a Randomized Complete Block Design having four replications. Nitrogen (N) was applied 120 kg ha^{-1} in split applications: half at sowing time and the other half at thinning (25 days after sowing). Each experimental unit was 5 x 8 m, accommodating ten rows equally spaced at 0.75 m. Initially all sowing was done at uniform seeding rate. However, the desired population was maintained by manual thinning spacing plants within the rows at 6 cm distances. Sowing dates were maintained as June 8, 16, 26, July 06, 13 and 24, 2010. Phosphorus as basal application was applied 80 kg P ha^{-1} at sowing. Azam variety was used for the study. Data was recorded on: days to emergence, tasseling and maturity; leaf area index (LAI); light interception; plants at harvest; yield and yield contributing traits. Data on days to emergence, tasseling and maturity was recorded by counting the days taken from emergence to the day when 50% plants within the central rows of an experiment unit responded. Leaf area indices (LAI) were measured non-destructively using the plant canopy analyzer (LI-2000, LI-COR, USA). The machine was programmed to take four consecutive readings; one above and three below the crop canopy for yielding an average reading for the LAI at post anthesis stage of the crop. Light interception by the canopy was measured with three light sensors (LI-190 and LI-191) and a data logger (LI-1400, LI-COR, USA). LI-190 was used for recording irradiance and LI-191 for reflectance and transmittance through the canopy. All measurements were taken on a clear sunny day between 11-13 h (Akmal and Janssens, 2004). Intercepted light by canopy was derived from field observations and the value was multiplied with cumulative PAR data. Total solar radiation was calculated from the given equation (Charles-Edward *et al*., 1986).

Solar radiation = 15.32136+7.853515*Sin
(22/7.*2* (day of the year +283)/365
PAR = Solar radiation * 0.47

Data regarding plants at harvest (m^{-2}) was counted in four central rows a day before the harvest. All plants in four central rows were harvested for dry matter and grain yield. Data regarding yield contributing traits i.e. grains row^{-1}, ear length (cm), grain cob^{-1} and 1000 grains weight (g) were measured at ten randomly selected plants harvested from the borders rows of each experimental unit. Dry matter and grains yield was recorded by harvesting plants in four central rows, the fresh ears were collected, weighed and shelled for the grain moisture contents. Grain yield was adjusted with the given equation. Dry matter was determined after sun drying the materials in field for about 10 days.

Statistical analyses of the data were carried out as per appropriate design using ANOVA procedure (Steel & Torie, 1980). Mean where found significant were separated using LSD ($p<0.05$).

Results and Discussion

Data regarding growth phenology i.e. days to emergence, tasseling and maturity in response to the sowing date of maize are shown in figure 1a. The duration in days to emergence, tasseling and maturity did decrease when sowing was delayed from June 08 onwards. This decreasing response in the growth phenology for the period from June 08 to July 03 was significantly different in sowing date but with a non-significant difference in days to emergence and maturity from July 03 onwards. The days taken by June 08 sowing was the highest (91.75 days) for physiological maturity but decreased when sowing was delayed until June 16 (86.25 days). Further delay form June 16 to 26 decreased ($p<0.05$) days to complete physiological maturity (82.25 days). The July 3 to 24 sowing did not differ in maturity duration of the maize crop. Proper selection of sowing date optimizes growth of the plants. The delay sowing has decreased photoperiod, intensity and duration of the solar radiation and mean thermal unit for the crop growth and development which has delayed the emergence and/or vegetative as well as reproductive durations of the crop life cycles (Cirilo & Andrade, 1994, 1996). We knew that the crop life cycle is comprised of vegetative (open circles) and reproductive (closed circles) durations which by delay sowing of maize crop affected adversely (Fig. 1b). The figure revealed that both vegetative and reproductive durations remained stable for a while for the sowing made on June 06 to July 03 but thereafter it disturbed slight (July 13) to moderate (July 24) with a higher vegetative and a lower reproductive durations of the crop life cycle. Delay sowing from June to July has adversely affected the prevailing weather conditions e.g. availability of the solar radiation, duration and intensity, the mean thermal temperature response on the crop growth phases and responses of the day to night photo fluctuations. The crops to adjust itself with these changes and to utilize the resources e.g. moisture, nutrients and solar radiation, optimum it has to be grown on a reasonable period of time (Sun *et al*., 2007; Grassini *et al*., 2011).

Leaf area index (LAI) was observed the maximum for the treatment sowing date June 16 (Fig. 1c) and decreased consistently thereafter for every delay in the sowing date till July 24. The delay sowing from June 08 to June 16 showed an unusual increase in the LAI. Plant population at harvest is an important parameter of maize in the area because a number of plants cannot reach maturity due to many unavoidable factors e.g. the moon-soon out-breaks and high winds at post anthesis stage of the crop. However, plants at harvest by the delay sowing did not differ for the experiment for the sowing made from June 08 to July 24. A slight but non-significant reduction was observed for July 24 sowing (Fig. 1d). Increased LAI in early sowing was in agreement with literature (Foster & Timmermans, 2009; Akmal *et al*., 2010). This increased in the LAI at early sowing might be due to increase in leaf production and leaf area duration due to more solar light and thermal units available for the growing period.

Data regarding grain rows cob^{-1} did not show any significant changes ($p<0.05$) in maize when planted between June 08 to July 24 with a ten days interval in the season (Fig. 1e). However, stable to moderate reductions in the ear length (cm) was observed when sowings was delayed from Jun 08 onwards. A slight increase in ear length was observed for sowing date Jun 08 to Jun 16, but thereafter a consistent reduction was reported in ear length when sowing delayed from June 16 to July 24 in the season. The grain number ear^{-1} did not differ ($p<0.05$) when maize was planted on June 16 and 26 in the season (Fig. 1f). However, sowing made on July 24 showed significantly the lowest grain ear^{-1} than any other sowing date. Contrary to that thousand grain weight (g) did decrease ($p<0.05$) when sowing delayed from June 16. Sowing of June 08 and 16 did not differ in the thousand grains weight but did decrease ($p<0.05$) thereafter until July 24. Sowing date for July 13 and 24 also did not differ in thousand grain weights but found the lowest from any of the early sowing date. The non-significant effects on ear length and grain number data revealed that climate change did not affect growth of the reproductive organs at the developmental stages. Contrary to that thousand grains weights, showed marked reduction ($P<0.05$). It might be due to either slow grains development and/or limited photo-assimilates partitioning for the grains (Otegui & Anrade, 2000; Giunta *et al*., 2009).

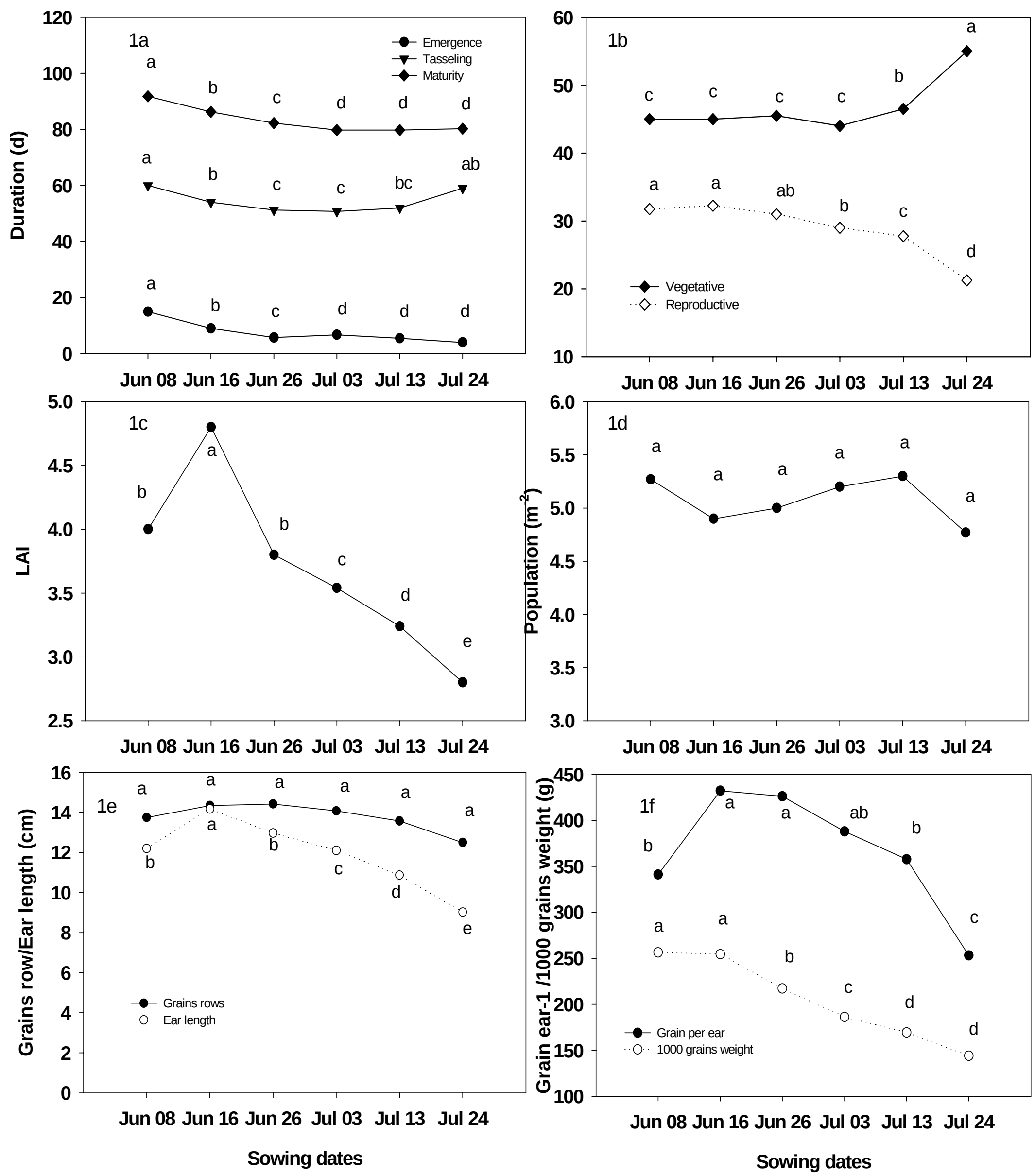

Fig. 1. The sowing date effects on emergence, tasseling, maturity durations (1a), vegetative and reproductive durations (1b), leaf area index (1c), plant population at harvest (1d), grain rows cob^{-1} and ear length (1e) grain number cob^{-1} and thousand grains weight (1f) during summer 2010 at Peshawar, Pakistan. Same letter on a parameter in each window shows non-significant effect using LSD.

Data regarding dry matter, grains yield (g m^{-2}), harvest index and radiation use efficiency (RUE) influenced by different sowing date of maize is shown in figure 2. The figure revealed almost common smooth decreasing trends for dry matter and grains yields (Fig. 2a). Sowing made on June 08, 16 and 26 did not differ in dry matter yield. Nevertheless, sowing of June 26 and July 03 also did not show ($P<0.05$) any difference in dry matter yield. July 13 showed lower dry matter yield than July 03. The lowest ($p<0.05$) dry matter yield was reported for July 24 sowing date. Regarding grain yield data, the highest yield was observed for sowing of June 16, followed by June 08. Sowing of June 26 and Jun 08 were non-significant form each other. Likewise, June 26 did vary in grain yield from sowing done on July 03. The July 03 did differ in grain yield from July 13 sowing date. The lowest grain yield was observed for July 24 sowing date. Harvest index is ratio of the grain to total yield (dry matter and grains). Harvest index of maize initially increased, remained more or less stable and then decreased when sowing was delayed from June 08 to July 24 (Fig. 2c). Sowing done in June did not differ ($p<0.05$) from each other for harvest index but the early sowing of June 08. Likewise, sowing made in July also did not differ from each other for the harvest index. Both dry matter and grain are economic yield contributors of maize in the area and has shown a significant declining effect by the delay sowing. This relationship of dry matter to grain yield for the different showing date treatments was found linear (Fig. 2b) and positively correlated (r^2=0.95). The slope of the regression ‘b’ therefore could be used as yield loss in maize production under the changing climate of the area. The relationship showed about 1.65 g m^2 loss in maize production when sowings delayed from June 08 to July 24 in the area. Results from the present study agree with findings of Sun *et al*., (2007) and Grenz *et al*., (2005).

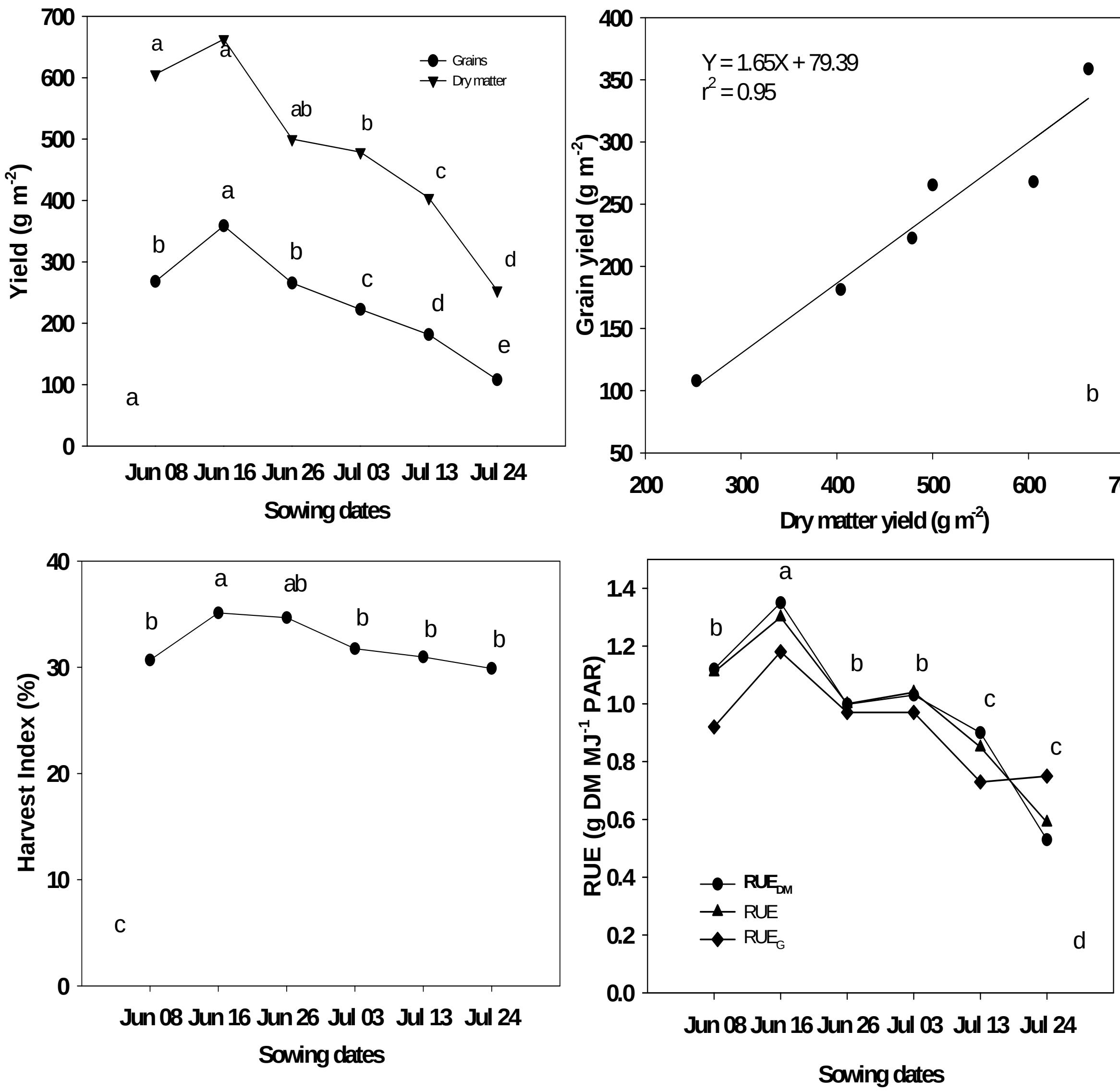

Fig. 2. Maize response to sowing dates for (a) dry matter and grain yield (g m^{-2}), (b) dry matter and grain yield relationship, (c) harvest index and (d) radiation use efficiency.

Radiation use efficiency (RUE) is a stable function of biomass production in relation to cumulative solar radiation intercepted during the crop growth and development. The concept of RUE has a great potential for prediction of crop productivity and was used by the Mkoga (2010); Charles-Edwards (1986) and many others to study the effect of climate on productivity. We calculate the ratio of total biomass (RUE), dry matter (RUE_{DM}) and grain (RUE_G) $unit^{-1}$ interception of the solar radiation (g MJ^{-1} PAR) by delay sowing of maize crop (Fig. 2d). It depict from the figure that the highest RUE was obtained for June 16 sowing. A significant ($P<0.05$) reduction in the RUE was estimated when sowing was delayed from June 26 onwards in the season. RUE did not differ for sowing made on June 26 and July 03. Likewise, RUE did not influence for the sowing made on July 13 and 24. Sowing of July 13 and 24 did show a decrease in the RUE for dry matter but non-significant effect for grains. A significant decrease in RUE of maize crop has also been reported in literature by delay in sowing (Confalone *et al*., 2010; Otegui & Anrade, 2000) and confirms the estimates of the data.

Conclusion

Results of the study revealed that delay sowing of maize in the season has relatively squeeze the reproductive phase of development with a substantial reduction in the very late sowing date which adversely affected grains development and hence resulted lower grain index which caused loss for the grain yield. No doubt, that the climate change has an adverse effect on growth and development and hence results losses in dry matter and yield. A reduction in productivity of maize by delay in sowing is the consequence of adverse weather effect on growth of maize in total and post anthesis stage in particular in the area.

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