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HOW THE COMPETITION OF *XANTHIUM STRUMARIUM* L. AFFECTS THE PHENOLOGICAL CHARACTERS OF MAIZE CROP

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Abstract

Maize is greatly influenced by competition of *Xanthium strumarium* L., having an adverse impact on its phonology and growth. Hence, to evaluate the effect of *X. strumarium* on phenological characters of maize, field experiments were conducted at the Research Farm of the University of Agriculture Peshawar, Pakistan during summer 2006 and 2007 using a randomized complete block design with split plot arrangement replicated three times. Four maize densities and seven varying densities of *X. strumarium* were tested. Data were recorded on emergence m^{-2}, days to tasseling, days to silking, days to maturity, and plant height of maize crop. All the maize phonological characters were significantly affected by the alternate crop and weed densities. The emergence m^{-2} was significantly reduced with increase in the densities of both the crop and weed. The tasseling stage of maize was delayed significantly at the highest maize density of 12.5 plants m^{-2} and at the *X. strumarium* densities ranging from 8 to 12 plants m^{-2}. The effect on silking stage of maize was significant statistically and it took 4-7 days for the maize plants in all the treatments to switch over from tasseling to silking stage. Weed density of 0 to 4 plants m^{-2} had a significant effect on days to maturity and the maturity stage was significantly delayed by increasing weed density from 6 to 12 plants m^{-2}. Plant height of maize was also influenced by the varying densities of either species, and plant heights were greater at 7.5 and 10 maize plants m^{-2}. Moreover, increasing the *X. strumarium* density from 0 to 6 plants m^{-2}, maize plant height progressively increased, however the plant heights declined at 8 to 12 *X. strumarium* plants m^{-2}. In light of the results it is concluded that both the crop and weed density do influence the phonological parameters of maize. However, crop density alone is not enough to cope effectively with the higher populations of *X. strumarium* weed; therefore, multiple cultural approaches should be employed to desirably improve the crop phenology when in competition with this weed.

Introduction

Maize (*Zea mays* L.) has a prominent place in the agricultural economy of Pakistan. At national level, the area under maize cultivation was 1.0521 m ha with annual production of 3.593 having an average yield of 3415 kg ha^{-1}. The figures in Khyber Pakhtunkhwa (KP) province were 0.5095 m ha, 0.9579 m t and 1880 kg ha^{-1}, respectively (MINFA, 2009) and it is mainly grown on irrigated lands (Sarir *et al*., 2005). Several factors are responsible for the lower average yield of maize in the country in which weeds have been the major menace among all the yield deteriorating factors and cause an average yield loss of 38% in maize (Hassan & Marwat, 2001). Weed competition has always been a serious problem in maize in the agro-ecological conditions of Khyber Pakhtunkhwa province. According to Rao (2000), an increase of one kilogram of weed growth corresponds to a reduction of one kilogram of crop growth. Among the weeds, common cocklebur (*Xanthium strumarium* L.) has become a noxious weed of maize in the locality (Afzal *et al*., 1994). It was introduced to Pakistan from Afghanistan during the Afghan war in the early 1980s due to massive migration of Afghan people and their livestock (Hashim & Marwat, 2002). It has allelopathic effects on crops (David *et al*., 2005; Casini, 2004). Its larger size makes it more competitive causing problems in maize production (Royal *et al*., 1997). Maize seed germination, its early growth, and fresh and dry biomass all are decreased by *X. strumarium* (Bhatt *et al*., 1994). Both the germination and vigor of maize seeds collected at harvest decrease with an increase in density of *X. strumarium* (Saayman *et al*., 1996).

Majority of our farmers still grow maize crop as have been grown for centuries. Using proper plant population densities, proper selection of suitable crops in crop rotation, intercropping of friendly crops at the same time etc. have always been ignored. Lower crop densities encourage weeds growth whereas higher crop densities negatively affect the leaf area and other phonological parameters. Crop competitive ability can be enhanced via its optimum population density, rapid root growth, leaf expansion rate, early root-shoot biomass accumulation, canopy closure and plant height (Ni *et al*., 2000; O'Donovan *et al*., 2000; Subhan-ud-Din *et al*., 2013). The competitiveness of a weed community with a crop depends on species composition, time of emergence and abundance. The recent rise in environmental awareness of the public, interest in organic food production and possible hazards of herbicide use has led us to device methods of weed management that could be economical and environment friendly (Parish, 1990). Thus, such crop management practices be devised that are productive, environmentally safe and socially acceptable (Mubeen *et al*., 2013; Karlen *et al*., 1995).

Keeping in view the importance of *X. strumarium* interference and the unknown impact of its densities which is critically important for competition with maize crop (Arif *et al.*, 2010; Khatam *et al.*, 2013), experiments were designed with the objective to analyze the ecological impact of varying *X. strumarium* populations on maize phonological parameters, to find out the optimum maize density having the best competitive characteristic with the associated weed and to recommend the proper time of weed control measures at the most appropriate density of the weed.

Materials and Methods

Field experiments were carried out at the Research Farm of the University of Agriculture Peshawar during 2006 and 2007 in RCB design with split-plot arrangement having three replications. The study site is at an altitude of 335 m above sea level and has a mean soil pH of 8.02 having 40% clay, 51.3% silt and 8.7% sand (Tariq *et al*., 2002). The main plots comprised of four varying maize densities: 5, 7.5, 10, and 12.5 plants m^{-2}, whereas seven contrasting densities of *X. strumarium* viz., 0 (control i.e. no *X. strumarium* plant), 2, 4, 6, 8, 10 and 12 plants m^{-2} were allotted to the subplots. The size of each experimental unit was 4 x 3 m^2. There were 4 rows of maize crop in each sub-plot, each row 4m long and spaced 0.75m apart. The soil was fertilized with 100 kg ha^{-1} N, 90 kg ha^{-1} P before sowing and 60 kg ha^{-1} N one month after sowing. Maize variety 'Azam' was sown in 2006 and 2007 with the help of a dibbler to maintain required plant to plant distance. Additional population of maize was maintained for replacing the missing plants in case of no germination or seedling mortality to keep the plant population constant. All the other agronomic practices were kept uniform during the growing season.

Data were recorded on crop phenology parameters i.e., percent emergence m^{-2}, days to tasseling, days to silking, days to maturity and plant height of maize crop. For emergence m^{-2}, maize seedlings were counted at the 2-3 leaf stage in the mid 2 rows of each subplot and their percentages were calculated to estimate percent emergence m^{-2}. Data on days to tasseling were recorded when more than 50% plants developed tassels in each treatment, by counting days from date of sowing till the completion of more than 50% tassels. For data on days to silking, days were counted from date of sowing till the completion of more than 50% silks. Days to maturity were recorded by counting the number of days from date of sowing till 75% of the plants reached physiological maturity. Plant height data were recorded at the time of crop physiological maturity. In this regard, ten plants were randomly selected from each experimental unit and their height was measured from base to the top of the plant and the averages were then computed. The experimental data were subjected to the analysis of variance appropriate for RCB design with split plot arrangement using statistical software MSTATC. Upon significant F-value, the means were separated by least significant test at $p \leq 5\%$ using the procedure outlined by Gomez & Gomez (1983). Significant means were separated by using LSD Test (Steel *et al*., 1997).

Results and Discussion

Percent emergence: Crop populations are usually selected for uniformity (phenotypically similar) that ensure synchronized seed germination. In contrary, weed populations are phenotypically heterogeneous in terms of temporal and spatial distribution (Harper, 1977). The ANOVA of the data indicated that maize planting density significantly affected maize percent emergence m^{-2} (Table 1). The seedlings of *X. strumarium*, on the other hand, emerged somewhat at the same time as the seedling emergence of the maize. Crop deterioration increases as the time between crop and weed emergence decreases (Cavero *et al*., 1999). In our results, the crop emergence m^{-2} was reduced gradually with increase in crop density. Maize emergence m^{-2} was not consistent among the maize densities due to the fact that many seedlings at higher densities either did not emerge or died later on because of intra-specific competition for resources (Sadia *et al*., 2013). The impact of *X. strumarium* density on maize percent emergence m^{-2} was significant, and here too the percent emergence progressively declined with rise in the weed density. Bhatt *et al*., (1994) reported allelopathic effects of *X. strumarium*, but it is not evident whether the decline in the crop emergence was due to the weed allelopathy because the weed germination stage is not generally believed to be having allelopathic effects. There is one possibility that the spiny *X. strumarium* fruits containing seeds might have the allelopathic effects on maize seedlings (Ahmad & Bano, 2013b). Time of weed emergence relative to the crop is also a very important factor in determining the biomass and seed production (James & Harvey, 1999).

Days to tasseling of maize: The first solid indicator of crop progress is the average tasseling date. Once tasseling dates are known, we can have a better speculation for the maturity prospects of the crop. The density of *X. strumarium* had a significant effect on days to tasseling of maize. The data in Table 1 showed that tasseling stage of maize was delayed at maize density of 12.5 plants m^{-2} and prompted at 5 plants of maize m^{-2}, indicating that very high maize density delays the tasseling stage. Days to tasseling were lessened in maize monocultures, which were though statistically similar to the plots with *X. strumarium* density of 2 and 4 plants m^{-2}. On the other hand days to tasseling were the highest in treatments with *X. strumarium* density of 12 plants m^{-2}, which was at par with the 8 and 10 plants m^{-2}, in 2006. Minimum days to tasseling of maize were recorded in plots with maize monocultures in 2007 which were statistically similar with *X. strumarium* density of 2 and 4 plants m^{-2}; while maximum days to tasseling were noticed at *X. strumarium* density 12 plants m^{-2} was at par with 10 plants m^{-2}. These results implied that with increase in the weed density, the tasseling stage of maize was delayed as more time was used by the plants in vegetative growth in order to increase plant height and leaf area for light and other resources when in competition. This discloses that tasseling is delayed with increase in plant density of either species due to intra or inter-specific competition (Mudarres *et al*., 1998; Noor-ul-Akbar, 1998).

Days to silking: Silking is another good indicator of the commencement of the reproductive growth stage of maize crop. One can assess the maturity of the crop when one comes to know about the silking dates. The data analyses revealed that there was a non significant effect of maize density on days to silking during 2006 and a significant ($p \leq 0.05$) effect during 2007. However, the days to silking values during 2007 for maize density of 7.5, 10 and 12.5 plants m^{-2} were statistically at par which indicated very slight but consistent differences. It was noted among all the experimental units that maize plants took four to seven days to transfer from tasseling to silking stage. Similarly, an increase in the days to silking was observed with the progressive increase in the density of *X. strumarium*. According to Mudarres *et al*., (1998) and Noor-ul-Akbar (1998), the days to tasseling and silking are greater at higher population density. Comparatively low humidity under the thin canopies might be the possible reason for the early silking at lower maize densities compared to delayed silking at higher maize density.

Table 1. Percent emergence m^{-2}, days to tasseling, days to silking, days to maturity and plant height of maize as affected by maize density and *X. strumarium* density during 2006 and 2007 in Peshawar, Pakistan.

	Maize percent emergence m^{-2}		Days to tasseling of maize		Days to silking of maize		Days to maturity of maize		Plant height (cm)	
	2006	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**
Maize density (m^{-2})										
5.0	89 a	86 a	54.2 c	52.4 b	61.6 d	57.8 b	93.9 c	91.9 c	163.8 b	159.1 bc
7.5	86 ab	83 b	56.9 b	52.7 b	62.3 c	58.6 a	95.0 b	92.6 bc	170.0 a	161.8 ab
10.0	83 b	81 bc	57.3 b	53.4 a	62.9 b	58.9 a	95.6 ab	93.0 ab	172.6 a	164.2 a
12.5	82 b	80 c	58.2 a	53.7 a	63.5 a	59.0 a	96.1 a	93.7 a	162.4 b	156.5 a
LSD values	**3.5**	**2.9**	**0.81**	**0.62**	**0.55**	**0.68**	**0.91**	**0.88**	**5.0**	**3.8**
Weed density (m^{-2})										
0	93 a	90 a	56.0 d	52.1 e	61.6 d	57.7 e	93.5 d	90.6 d	164.5 cd	158.2 c
2	90 b	87 b	55.9 d	52.5 de	61.9 d	58.0 de	93.4 d	90.8 cd	172.4 ab	160.3 bc
4	87 c	84 c	56.2 c	52.3 de	62.0 d	58.2 de	94.4 c	91.8 c	171.4 bc	163.3 b
6	83 d	81 d	56.9 b	52.9 cd	62.7 c	58.5 cd	95.2 bc	93.1 b	176.3 a	169.1 a
8	82 d	79 d	57.5 ab	53.5 bc	62.9 bc	58.9 bc	95.8 b	94.3 a	167.0 c	163.0 b
10	82 d	79 d	57.7 a	53.8 ab	63.4 ab	59.1 ab	96.7 a	94.4 a	162.1 d	157.2 c
12	78 e	76 e	58.1 a	54.2 a	63.7 a	59.5 a	97.1 a	94.8 a	156.6 e	151.7 d
LSD values	**2.5**	**2.3**	**0.70**	**0.64**	**0.63**	**0.56**	**0.79**	**1.01**	**4.7**	**4.0**
Interaction										
MD x WD	*	*	NS	*	*	NS	*	NS	*	*

Means of the same category followed by different letters are significantly different at $P \leq 0.05$ level using LSD test.
MD = Maize Density, WD = Weed Density, NS = Non Significant
* Significant at $p \leq 0.05$

Days to physiological maturity: Physiological maturity of maize is determined by the development of black layer in the placental-chalazal region of the seed (Tekrony *et al*., 1994) and by the progressive development of the milk line as a result of milky endosperm solidification, beginning at seed apex and ending at the base (Hunter *et al*., 1991). Results showed that minimum value for days to maturity was recorded at maize density of 5 plants m^{-2} while maximum value was noticed at maize density of 12.5 plants m^{-2} which was however statistically similar to the maize density of 10 plants m^{-2} (Table 1). This indicated that there was an intra-specific competition effect at higher maize densities; thus, the plants transferred the resources to vegetative growth causing delay in the reproductive growth which eventually increased the number of days to maturity (Mudarres *et al*., 1998). The data in Table 1 further showed that *X. strumarium* density significantly influenced the days to maturity of maize. The days to maturity increased progressively with increase in *X. strumarium* density. An early maturity of maize was observed in the pure stands of maize in both the trials but it was statistically comparable with the days to maturity of maize in plots with *X. strumarium* density of 2 and 4 plants m^{-2}. This showed that there was no significant difference for days to maturity of maize among the *X. strumarium* densities of 0, 2, and 4 plants m^{-2}. Thus, increasing the weed density delayed the maturity of maize which might be attributed to the fact that at higher densities the resources got more limited and the plants in competition used most of their resources in vegetative growth to get maximum height and root in order to facilitate their access to light and nutrients (Mahmood-ul-Hassan *et al.*, 2013. This resulted in a delay of the plants maturity. Maize maturity was also delayed by weed competition from quack grass and common lambsquarters in the experiments of Sibuga and Bandeen (1980).

Plant height (cm): Maize densities had a significant effect on plant height of maize during both the years. At a density of 5 plants m^{-2}, maize was prone to inter-specific competition which negatively influenced the crop growth and development. At the very high density of 12.5 plants m^{-2}, maize was in fact vulnerable to both the intra and inter-specific competition. Thus the growth and development of maize plants were restricted both at lower and very high densities contrary to the medium densities of 7.5 and 10 plants m^{-2} which were not that much vulnerable to either mode of competition. Therefore, it was observed in both the experiments that with increasing maize density from 5 to 10 plant m^{-2} plant height was increased but at maize density of 12.5 plants m^{-2} plant height of maize was reduced. The results were in line with those reported by Hassan (2000) and Noor-ul-Akbar (1998). The plant height of maize was significantly altered by *X. strumarium* density during both the years. Means of the data showed that increasing *X. strumarium* density from 0 to 6 plants m^{-2}, maize plant height progressively increased during both the years (Table 1). The canopy coverage of *X. strumarium* was more than maize crop due to which the crop plants gradually grew higher in competition with *X. strumarium* up to density of 6 plants m^{-2} in order to avoid competition for light but at *X. strumarium* density of 8, 10 and 12 plants m^{-2}, the maize plant height was diminished progressively. The results were in line with those reported by David & Kovacs (2007) who stated that higher *X. strumarium* density reduced maize plant height by 33% in weedy control plots compared to weed free plots. Maize stalk diameters were reduced by weed interference resulting in increased plant height but thinner stalks (Baldoni *et al*., 2000; Mishra, 2000; Coleman & Gill, 2005; Ahmad *et al.*, 2013a).

Conclusions

Maize phonological characters responded significantly to the alternate crop and weed densities. Maize seedlings emergence was reduced gradually with increase in crop density and so was the impact of the *X. strumarium* density. The tasseling stage of maize was delayed significantly at maize density of 12.5 plants m^{-2} and at *X. strumarium* densities of 8-12 plants m^{-2}. The impact on silking stage was though non significant; however it took 4-7 days for the maize plants in all the treatments to transfer from tasseling to silking stage. Weed density of 0-4 plants m^{-2} had no effect on days to maturity and then the maturity stage was significantly delayed by increasing weed density from 6 to 12 plants m^{-2}. Maize plant heights were optimum at 7.5 and 10 maize plants m^{-2}. On the other hand, increasing the *X. strumarium* density from 0 to 6 plants m^{-2}, maize plant height progressively increased but interestingly the plant heights declined at 8-12 *X. strumarium* plants m^{-2}.

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