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IMPACT OF TILLAGE, PLANT POPULATION AND MULCHES ON PHENOLOGICAL CHARACTERS OF MAIZE

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Abstract

Field experiments were conducted during 2006 and 2007 in Peshawar, using open pollinated maize variety "Azam" in RCB design having 3 factors viz., tillage, maize populations and mulches with split-split plot arrangements. Tillage levels (zero and conventional) were assigned to the main plots, populations (90000, 60000 and 30000 plants ha^{-1}) to sub-plots and four types of mulches (weeds mulch, black plastic mulch, white plastic mulch and mungbean as living mulch), a hand weeding and a weedy check were allotted to sub-sub plots, respectively. Data were recorded on days to tasseling, days to silking, days to maturity, leaf area of maize plant^{-1} (cm^2) and plant height (cm). Tillage affected leaf area of maize, where zero tillage resulted lower leaf area of 4094 cm^2 compared to conventional tillage (4722 cm^2). Different levels of plant populations affected all the physiological parameters. Days to tasseling, silking and maturity were more in higher plant population as compared to medium and lower plant population. Similarly, minimum leaf area plant^{-1} was recorded in higher plant population (3894 cm^2) than medium and lower plant population of 4398 and 4932 cm^2, respectively. Maximum plant height was recorded in hand weeding treatment (173 cm). However, it was statistically at par with black plastic mulch (171 cm), followed by weeds mulch (162 cm) and white plastic mulch (161 cm) as compared to weedy check (152 cm). Based on two years study it is suggested that even if tillage options and plant populations are a part of the weed management program, it should not be used as a sole management tool, as both have a negative impact on the phenological parameters of maize which subsequently affected the final yield and must be integrated and supplemented with other control methods.

Introduction

The increasing use of maize gives it a prominent place in agricultural economy in Pakistan. Maize was planted on an area of 1.017 million ha with an annual production of 3.0884 million tons with an average of 3037 kg ha^{-1} during 2006-07 (Anon., 2007). The average yield of maize in Pakistan is very low due to several yield reducing factors and weeds are the major factor among them affecting the whole phenology of the crop and causing an average yield loss of 38 % in maize (Hassan & Marwat, 2001). Tillage is used to destroy the weeds but due to the concept of less or no soil disturbance (conservation tillage and no-tillage) it is avoided as the undisturbed soil possesses higher microorganisms and biological activity (Sturny, 1998). Conservation tillage practices including minimum and no-tillage have an important role to overcome the physical limits to productivity of agricultural land (Somervaille, 1995). Similarly, the majority of the farmers in our country neither follow the recommended rate of fertilizer nor the recommended plant population due to illiteracy and resource impoverished background. Band placement of N and optimum plant density produced higher grain yield than broadcast N application (Hassan *et al*., 2013). Higher plant densities affect leaf area index (LAI), plant height, ear size and yield negatively (Wiyo *et al.,* 1999). At higher densities shading by the taller plants could reduce the photosynthetic rate of the lower growing plants and thereby reduce their yields (Zhuang & Yu-Bi, 2013). In conventional tillage systems, crop residues and associated weeds are removed while in conservation tillage, plant cover is managed to induce the establishment of mulches and in case of living mulches or intercrops reduced weed population, boosted maize performance and enhanced land utilization (Ortega, 1991; Hussain *et al*., 2013). Similarly cover crops reduced abundance and weed biomass (Unger & Ackermann, 1992). The recent upsurge 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; Mubeen *et al*., 2013). For example priming is an efficient technique for enhanced seed emergence and seedling establishment under optimal and sub-optimal available soil moisture conditions (Sudozai *et al.*, 2013). Therefore, such crop management practices should be devised that are productive, environmentally safe and socially acceptable (Karlen *et al*., 1995). Keeping in view the importance of zero tillage, manipulation of plant population and mulches as the tools of organic and sustainable farming, two experiments were designed to analyze their efficacy in maize. The objectives were to evaluate the effect of zero-tillage and conventional tillage systems in combination with varying maize populations and various types of mulches, on various phonological characters of maize that are directly or indirect associated with yield and to recommend in the light of these experiments the most economical and feasible weed control method for the farmers.

Materials and Methods

Two field experiments were carried out at New Developmental Farm, The University of Agriculture Peshawar during 2006 and were repeated in 2007 using RCB design with split-split-plot arrangements, having 3 replications. Two levels of tillage (zero & conventional) were assigned to the main plots, three populations (densities) of maize (90000, 60000 and 30000 plants ha^{-1}) to the sub-plots and four types of mulches, a hand weeding and a weedy check were assigned to sub-sub plots. Each experimental unit comprised 4 rows of maize, 4 m long and 0.75 m apart. In case of conventional tillage land was prepared by ploughing the field thrice followed by harrowing. The soil was fertilized in both tillage systems with 100 kg ha^{-1} nitrogen, 60 kg ha^{-1} phosphorus before sowing and 60 kg ha^{-1} N was applied one month after sowing. Maize variety 'Azam' was sown on June 25 in 2006 and June 28 in 2007 with the help of dibbler. Higher seed rate was used and then thinning was done to adjust the desired populations of maize. Two rows of mungbean (variety NM-92) were planted as living mulch. The other treatments like black plastic, white plastic and weeds as mulch were applied 4 days after crop emergence. In the weeds mulch, weeds were cut and spread in 4-6 inches layer between maize rows. In the hand weeding treatment, weeding was done twice (30 and 45 days after crop emergence). All other agronomic practices were kept uniform during the growing season of maize.

Data were recorded on days to 50% tasseling, silking leaf area of maize plant^{-1} at anthesis (cm^2) plant height (cm), and days to 50% physiological maturity. The data recorded individually for each parameter were subjected to the ANOVA technique using MSTATC and MS Excel. Significant means were separated by using LSD Test (Steel & Torrie, 1980).

Results and Discussion

Field experiments were conducted in June, 2006 and repeated in June, 2007. In general, the average temperature was higher in 2007 as compared to 2006 but rainfall during 2007 was lower than for 2006.

Days to tasseling: The first signal of the initiation of reproductive growth of maize is tasseling and silking. Once tasseling dates are known, we can have a better speculation for the maturity prospects of the crop. As shown in the Table 1, the effect of tillage practices was not significant, whereas effects of plant populations and mulches were significant on days to tasseling. None of the interactions were significant. The highest plant population (90000 plants ha^{-1}) took 59 days to tasseling as compared to 57 days in other populations (60000 plants ha^{-1} and 30000 plants ha^{-1}). Tasseling took 60 days each in living mulch and hand weeding plots, followed by weeds mulch and weedy check by taking 57 days each, followed by 56 days in each of black plastic and white plastic mulches (**Table** 1). Since the number of seedlings was kept uniform therefore plant density was not affected by the tillage and no apparent stress was found in both the tillage systems. However, researchers have reported different findings. According to Tangadulratana (1985) tillage did not affect the flowering dates, whereas Cox *et al.,* (1990) found that tasseling took more days in no-tillage situation compared to tilled one.

Delayed tasseling at higher plant densities might be due to lower soil temperature in higher populations, compared to thin canopies in lower populations. These results for population effect are similar with the work of Akrapat & Choomsai, (1985) who stated that increasing plant population delayed tasseling and silking. Mudarres *et al.,* (1998) and Ahmad and Khan (2002) also reported that higher maize population prolonged days to tasseling. Noor-ul-Akbar (1998) also investigated that days to tasseling, silking and maturity was increased when maize plant population was increased. Similarly, Oleksy *et al.,* (2001) investigated that higher plant population delayed maturity.

Table 1. Days to 50% tasseling, days to 50% silking and leaf area (cm^2) of maize as affected by tillage, plant population and mulches during 2006 and 2007.

Factor	Level	Days to 50% tasseling	Days to 50% silking	Leaf area of maize plant^{-1} (cm^2)
		2006-07	2006-07	2006-07
Tillage	Zero	57	63	4094*
	Conventional	58	63	4722
Populations	90000 plants ha^{-1}	59a	64a	3894c
	60000 plants ha^{-1}	57b	63b	4398b
	30000 plants ha^{-1}	57b	62c	4932a
	LSD	**0.68**	**0.57**	**86**
Treatments	Weeds mulch	57b	62c	4432b
	Black plastic	56c	61d	4844a
	White plastic	56c	61d	4426b
	Living mulch	60a	66a	4360b
	Hand weeding	60a	66a	4848a
	Weedy check	57b	63b	3537c
	LSD	**0.84**	**0.67**	**105**
Interactions	Tillage x Population	NS	NS	*
	Tillage x Mulches	NS	NS	*
	Population x Mulches	NS	NS	*
	Tillage x Population x Mulches	NS	*	*

* = Significant at p≤0.05, ** = Significant at p≤0.01, NS = Non significant

The early tasseling in both plastic mulches (black as well as white) could be attributed to increase in soil temperature under plastic mulch treatments, which may have promoted early tasseling. These findings for the plastic mulches are in agreement with the results of Rifin (1988) that mulches induced early tasseling and silking in maize. These results are also in line with the work of Yonghe (1994) who reported that under different cropping systems, plastic mulch significantly raised the soil temperature, kept soil water content stable and enhanced microbial activity and as a result crops grew faster. Plastic mulches have the potential to accelerate maturity (Li-Yan *et al.,* 2003). While maximum days to tasseling in living mulch might be due to the interspecific competition between maize and living mulch. Living mulch competed with maize as maize itself at higher plant populations. Hussain *et al.,* (2003) reported that days to tasseling increased with living mulch in maize. Hand weeding also increased number of days to tasselling and silking compared to control (Nawab *et al.,* 1997).

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. Statistical analysis of the data revealed that the effect of tillage practices was not significant, whereas plant population and mulches had a significant effect on days to silking. Tillage x plant population x mulch interaction was significant (Table 1). Highest plant population (90000 plants ha^{-1}) took 64 days to tasseling compared to 63 and 62 days in the 60000 and 30000 plants ha^{-1}, respectively. Silking took 66 days each in living mulch and hand weeding, followed by weedy check by taking 63 days, weeds mulch took 62 days, black plastic and white plastic took 61 days each to reach silking stage (Table 1), respectively. Since the population was same in different tillage practices and no stress was observed, therefore, this might be the possible explanation. These results for tillage effects are in line with the findings of several researchers. Sharma *et al.,* (1988) reported that different tillage systems did not affect silking and maturity of maize. Tangadulratana (1985) also reported that tillage system did not change time of flowering in maize. Cox *et al.,* (1990) also found that delayed silking under zero tillage system compared to conventional tillage systems.

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. These results for plant population effects are in agreement with the work of Akrapat & Choomsai (1985), Mudarres *et al.,* (1998) and Ahmad & Khan (2002) who reported that higher maize densities prolonged days to silking. Similarly, Noor-ul-Akbar (1998) and Oleksy *et al.,* (2001) also reported that higher maize populations delayed tasseling, silking and maturity.

The early silking in plastic mulches as well as weeds mulch might be attributed to the effects of mulch material in increasing soil temperature that induced early flowering and maturity. These results for plastic mulches are in agreement with those of Kwabiah (2003) and Rifin (1988) that plastic mulch enhanced silking compared to uncovered treatments. Yonghe (1994) also reported that under different cropping systems, plastic mulch significantly raised the soil temperature keeping soil water content stable, which, resulted in faster growth of the crops. Plastic mulches have the potential to accelerate maturity thereby ensuring silage corn crops achieve acceptable dry matter accumulation in cool climate regions (Li-Yan *et al*., 2003). While delayed silking in living mulch might be due to lower soil temperature under the denser cover of living mulch. These results for the living mulch are in line with the findings of Hussain *et al.,* (2003) that living mulch delayed silking in maize. On the other hand Nawab *et al.,* (1997) reported that hand weeding (30 days after emergence) increased number of days to tasselling and silking as compared to weedy check and weeding 45 days after emergence. In the tillage x population x mulches interaction, silking was delayed more in the zero tillage system with increasing plants population as compared to conventional tillage system. The tendency of delayed silking with increasing plant population was noted in all mulches (Table 1).

Leaf area plant^{-1}: There was a significant effect ($p \leq 0.05$) of tillage, plant population and various mulches on leaf area plant^{-1} of maize. All of the interactions were also significant (Table 1). Leaf area plant^{-1} was less under zero tillage (4094 cm^2) as compared to conventional tillage (4722 cm^2). The analysis of the data showed that leaf area plant^{-1} increased in linear fashion with decreased in plant population of 90000 plants ha^{-1} (3894 cm^2) to 60000 plants ha^{-1} (4398 cm^2) and 30000 plants ha^{-1} (4932 cm^2), respectively. The highest leaf area plant^{-1} was obtained in the hand weeding treatment (4848 cm^2) and black plastic mulch (4844 cm^2), followed by weeds mulch (4432 cm^2), white plastic (4426 cm^2) and living mulch (4360 cm^2), respectively against 3537 cm^2 in weedy check (Table 1). Although zero tillage did not hinder the establishment and early growth of the maize, yet later on may have affected root development as compared to conventional tillage. The negative effect on root development may have led to slower flow of water and nutrients from soil to the plant. These results for tillage effect are in agreement with those of Tangadulratana (1985) that conventional tillage was superior to zero tillage regarding leaf area and leaf area index. Karunatilake, (2000) also reported higher leaf area plant^{-1} in conventional tillage compared to no-tillage in maize and thus was attributed the higher leaf area plant^{-1} in conventional tillage to abundant root growth compared to that of zero tillage.

Leaf area plant^{-1} was smaller at higher plant populations probably because of crowding effect of the plant and due to higher intraspecific competition for space, moisture and nutrients. Our results for plant population effect are in agreement with the findings of Akrapat & Choomsai, (1985) who reported that increasing plant population decreased leaf area plant^{-1}. Bahadur *et al.,* (1999) also reported that higher maize population decreased leaf area plant^{-1} but increased leaf area index. By increasing plant population they reduced the distance between plants and consequently increased intraspecific competition, which as a result reduced the size of individual plants (Johnson & Wilman, 1997: Ammanullah *et al*., 2009).

While the highest leaf area plant^{-1} in the hand weeding and black plastic mulch might be attributed to effective weed control, thus providing favorable conditions. Whereas the lower leaf area plant^{-1} in the rest of the treatments might be due to higher weed infestation and more competition. Yonghe (1994) also reported that plastic mulch significantly raised the soil temperature keeping soil water content stable, which, resulted in faster growth with higher dry matter yield as compared to uncovered treatments. Plastic mulches have the potential to accelerate vegetative growth (Kwabiah, 2003). Mulch significantly increased leaf area plant^{-1} and increased leaf area index (Iqbal & Anwar-ul-Hassan, 2003; Rifin, 1988). The lowest leaf area plant^{-1} in the weedy check plots is supported by the results of Hussein (1997) that weeds competition significantly decreased leaf area and leaf area index.

In the tillage x population interaction, leaf area plant^{-1} was decreased with increasing plants population in both the tillage systems. In the tillage x mulches interaction zero tillage affected leaf area plant^{-1} negatively in all mulches except in the weedy check where both the tillage systems had statistically similar leaf area plant^{-1}. The interaction between population x mulches also showed a trend that leaf area plant^{-1} decreased with increasing plant population. The same trend is evident in almost all of the mulches, hand weeding and weedy check. In interaction among tillage x population x mulches, leaf area plant^{-1} increased across tillage i.e from zero tillage to conventional and decreased across plant populations i.e from 30000 plants ha^{-1} to 90000 plants ha^{-1}.

Plant height (cm): Analysis of data indicated that the effect of tillage practices was not significant, whereas effect of plant population and mulches was significant on plant height of maize. While among the interactions only tillage x population x mulches was significant (Table 2). Plant height increased at 90000 plants ha^{-1} (167 cm) and decreased at 60000 plants ha^{-1} (161 cm) and 30000 plants ha^{-1} (159 cm). Maximum plant height (173 cm) was recorded in hand weeding and black plastic mulch (172 cm), followed by weeds mulch (162 cm) and white plastic mulch (161 cm), followed by living mulch (154 cm) against 152 cm in weedy check (Table-2). Since the early growth and development under both the tillage systems was alike, this may explain the similar plant heights under both the tillage systems. These results for the tillage effect are in agreement with the findings of Sharma *et al.,* (1988) who reported that all parameters including plant height was not affected significantly by the two tillage systems. Al-Ghrerie (1988) also reported that the two tillage systems (zero tillage and conventional tillage) had no significant affect on plant height of maize. In contrary Elliot *et al.,* (1993) stated that as the number of plowings and harrowings increased, weed biomass and time required for weeding were reduced and growth of maize increased. While taller plants at higher plant populations might be due to the increase in competition for light. These results for populations effect are in line with the work of Hashemi *et al.,* (2005) and Tetio-Kagho & Gardner (1988) that increasing the maize density increased plant height and vegetative dry matter accumulation. Whereas Noor-ul-Akbar (1998) also reported that higher maize population increased plant height. Tollenaar *et al.,* (1994) reported that increasing plant density from 4-10 plants m^{-2} reduced biomass of individual plants of maize yet increased plant height. Increasing plant density significantly increased plant height (Ahmad & Khan, 2002). In Pakistan biomass is given importance as stalks and other plant materials are used as fodder and the cobs and stubbles are used as fuel for cooking. Therefore the instant results suggested that tillage and mulches significantly increase the phonological parameters.

Table 2. Plant height (cm) and 50% physiological maturity of maize as affected by tillage, plant population and mulches during 2006 and 2007.

Factor	Level	Plant height (cm)	Days to 50% physiological maturity
		2006-07	**2006-07**
Tillage	Zero	162	96
	Conventional	162	96
Populations	90000 plants ha^{-1}	167a	97a
	60000 plants ha^{-1}	161b	96b
	30000 plants ha^{-1}	159b	96b
	LSD	**4.48**	**0.64**
Treatments	Weeds mulch	162b	97b
	Black plastic	171a	94d
	White plastic	161b	95c
	Living mulch	154c	98a
	Hand weeding	173a	97b
	Weedy check	152c	97b
	LSD	**4.24**	**0.78**
Interactions	Tillage x Population	NS	NS
	Tillage x Mulches	NS	NS
	Population x Mulches	NS	*
	Tillage x Population x Mulches	*	NS

* = Significant at $p \leq 0.05$, ** = Significant at $p \leq 0.01$, NS = Non significant

The plants grew taller in the hand weeding probably due the effective weed control, better allocation of the available resources towards crop rather than weeds. While better plant heights in the black plastic mulch might be attributed to the ability of black plastic to raise soil temperature, to prevent the germination of light sensitive weed seeds and consequently by providing an efficient weed control. These results for mulches effect are in line with the work of Jedrszczyk *et al.,* (2005) who reported that living mulches decreased the height by 62.5-67.1% under full season weedy conditions compared to weeding. In the tillage x population x mulches interaction plant height increased with increase in plant population in zero tillage but in conventional tillage system plant height either remained constant or decreased with increase in plant population as evident in hand weeding of conventional tillage plots (Table 2).

Days to physiological maturity: The effect of tillage was not significant, whereas plant population and mulches had a significant effect on days to physiological maturity of maize, while among the interactions population x mulches was significant (Table 2). The highest plant population (90000 plants ha^{-1}) took 97 days to maturity compared to 96 days in other populations (60000 and 30000 plants ha^{-1}). Maturity took 98 days in living mulch, followed by hand weeding, weeds mulch and weedy check taking 97 days each, followed by 95 days in white plastic and 94 days in black plastic mulches to reach physiological maturity (Table 2). These results for the tillage effect are in line with the findings of Tangadulratana (1985) who reported that different tillage practices did not delay physiological maturity in maize. Similar results have been obtained by Sharma *et al.,* (1988) that different tillage systems recorded statistically similar dates for tasseling, silking and maturity. Zero tillage and conventional tillage systems did not affect days to maturity (Al-Ghrerie, 1988).

Delayed physiological maturity at higher plant populations might be because of shading effect under thick canopies of maize plants against lower populations, where the direct sunlight may heat up soil surface. These results are in agreement with the findings of Mudarres *et al.,* (1998) that physiological maturity was delayed at higher plant populations. Increasing plant population delayed physiological maturity (Akrapat & Choomsai, 1985). According to Ahmad & Khan (2002) higher maize populations prolonged days to maturity. Noor-ul-Akbar (1998) also reported that days to tasseling, silking and maturity increased when maize plant population was increased. Higher plant population led to delayed maturity (Oleksy *et al.,* 2001).

Plastic mulch raised soil temperature, which might have accelerated maturity of maize plants. These results for mulches effect are in line with the work of Yonghe (1994) that plastic mulch significantly raised soil temperature, kept soil water content stable and enhanced microbial activity as a result crops grew faster. Kwabiah (2003) also reported that plastic mulch reduced days to physiological maturity as compared to uncovered treatment. Plastic mulches have the potential to accelerate maturity (Li-Yan *et al*., 2003). In the population x mulches interaction days to physiological maturity increased with increasing plant population in all mulches, hand weeding and weedy check (Table 2). In a similar studies, Khan *et al.,* (2013) reported that nutrients availability and weed control significantly affected all the parameters of maize.

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