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IMPACT OF TILLAGE, PLANT POPULATION AND MULCHES ON BIOLOGICAL YIELD 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 the 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 fresh weed biomass (kg ha^{-1}), leaf area of maize $plant^{-1}$ (cm^2), leaf area index and biological yield (kg ha^{-1}). Fresh weed biomass was not affected significantly by the years, whereas all other factors affected the fresh weed biomass. Zero tillage resulted in maximum fresh weed biomass of 183 kg ha^{-1} as compared to 165 kg ha^{-1} in the conventional tillage. While lesser weed biomass (151 kg ha^{-1}) was recorded in the highest population of 90000 plants ha^{-1} as compared to 60000 plants ha^{-1} (168 kg ha^{-1}) and 30000 plants ha^{-1} (183 kg ha^{-1}), respectively. Minimum fresh weed biomass was recorded in hand weeding (112 kg ha^{-1}) and statistically at par with black plastic mulch (120 kg ha^{-1}), followed by weeds mulch (164 kg ha^{-1}), white plastic mulch (191 kg ha^{-1}) and living mulch (195 kg ha^{-1}) as compared to weedy check (260 kg ha^{-1}). With zero-tillage biological yield was 7708 kg ha^{-1} as compared to 7980 kg ha^{-1} in conventional tillage. Similarly, increasing crop density increased biological yield, having 7000, 7992 and 8541 kg ha^{-1} in 30000, 60000 and 90000 plants ha^{-1}, respectively. However, biological yield of individual plants was decreased with increasing plant population. Similarly, mulches, hand weeding and weedy check also affected the biological yield of maize. Significantly higher biological yield of 9118 kg ha^{-1} was recorded in the hand weeding as compared to weedy check (5537 kg ha^{-1}) and black plastic mulch (8982 kg ha^{-1}). However, based on high cost of plastic, its use is not economical. With weeds mulch (7956 kg ha^{-1}), white plastic (7934 kg ha^{-1}) and living mulch (7540 kg ha^{-1}) yield was not enhanced, as otherwise expected. 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, instead it must be integrated and supplemented with other control methods, like mulches, hand weeding and/or herbicides.

Introduction

The increasing use of maize gives it a prominent place in agricultural economy. In Pakistan it was planted on an area of 1.0169 m ha with an annual production of 3.0884 m tons with an average of 3037 kg ha^{-1} during 2006-07. While in the North West Frontier Province, it was planted on 0.5161 m ha, with annual production of 0.9186 m tons with average of 1780 kg ha^{-1}, (Anon., 2007). The average yield of maize in Pakistan is very low due to several factors and weeds are the major one among them causing an average yield loss of 38% in maize (Hassan & Marwat, 2001). The phenomenon of growing crops with less or no soil disturbance is termed as conservation tillage, which has an important role to overcome the physical limits of agricultural land (Somervaille, 1995). On the other hand no-tillage is a crop production system without any soil disturbance from previous harvest to direct seeding. Undisturbed soil possesses higher microorganisms and biological activity (Sturny, 1998). Similarly, the majority of farmers in our country do not follow the recommended plant population density. Higher plant densities affect leaf area index (LAI), grain yield, ear size and yield negatively (Wiyo *et al*., 1999). In conventional tillage systems, crop residues and associated weeds are burned, incorporated with soil or used for grazing and as feed (Ortega, 1991). In contrast, in conservation tillage, plant cover is managed to induce the establishment of mulches which, protect the soil surface, provide organic matter and promote better interception and infiltration of rain or irrigation water (Ortega, 1991). 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). 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 weed control under zero-tillage and conventional tillage systems in combination with varying maize populations and various types of mulches, to find out the effect of cultural control on biological yield of maize and to recommend the most economical and feasible weed control method for the farmers.

Materials and methods

Two field experiments were carried out at Agriculture Research Farm, NWFP Agricultural University Peshawar during 2006 and 2007 in RCB design with split-split-plot arrangements, having 3 replications. Two levels of tillage (zero and 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, 4m 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} N, 60 kg ha^{-1} P before sowing and 60 kg ha^{-1} N one month after sowing. Maize variety ‘Azam’ was sown on June 25 in 2006 and June 28 in 2007 with the help of dibbler. 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. Two rows of mungbean (variety NM-92) were planted as living mulch. The other treatments like black plastic mulches, white plastic mulch 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 as organic mulch. In the hand weeding treatment weeding was done twice (30 and 45 days after crop emergence). All the other agronomic practices were kept uniform during the growing season.

Data were recorded on fresh weed biomass, leaf area of maize $plant^{-1}$ at anthesis (cm^2), leaf area index of maize crop and biological yield (kg ha^{-1}). Five plants from each sub-sub-plot were selected randomly after complete anthesis. The leaves of each plant were cut with scissors and put in plastic bags. Leaf area was measured with the help of leaf area meter model LI-3100. The mean of the sample determined the leaf area $plant^{-1}$. The mean leaf area $plant^{-1}$ was multiplied by number of plants m^{-2} of that treatment to get leaf area index. All the existing weeds from the individual treatments were pulled out 56 days after sowing, weighed and the data was converted to kg ha^{-1}. For biological yield two central rows of each sub-plot were harvested at maturity, air-dried and weighed by spring balance and converted to kg ha^{-1}. The data recorded individually for each parameter were subjected to the ANOVA technique. Significant means were separated by using LSD Test (Steel & Torrie, 1980).

Results and discussion

Leaf area plant^{-1} and leaf area index: There was a significant effect ($p \leq 0.05$) of tillage, plant population and various mulches on leaf area plant^{-1} and leaf area index of maize (Table 1). All of the four types of interactions were also significant. Leaf area plant^{-1} and leaf area index were less under zero tillage as compared to conventional tillage. Leaf area plant^{-1} decreased, while leaf area index increased in linear fashion with increase in plant population. 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. 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. By increasing plant population we reduced the distance between plants and consequently increase intraspecific competition, which as a result reduce the size of individual plants in terms of leaf size, number of leaves and total leaf area (Johnson & Wilman, 1997). Similarly, increasing plant populations increased leaf area index of maize (Tetio-Kagho & Gardner, 1988; Rifin, 1988). While the highest leaf area plant^{-1} and leaf area index in the hand weeding and black plastic mulch might be attributed to their weed control, thus providing favorable conditions. Plastic mulches have the potential to accelerate vegetative growth.

Fresh weed biomass (kg ha^{-1}): Statistical analysis of the data showed that the effect of tillage practices, plant populations and mulches was significant on fresh weed biomass. While among the interactions only population x mulches was significant (Table 1). Fresh weed biomass was higher in the zero tillage compared to conventional tillage. While minimum fresh weed biomass was recorded in higher plant populations as compared to lower plant population. Minimum fresh weed biomass was recorded in the hand weeding (112 kg ha^{-1}) and black plastic mulch (120 kg ha^{-1}), followed by weeds mulch (164 kg ha^{-1}), followed by white plastic (191 kg ha^{-1}) and living mulch (195 kg ha^{-1}) against 260 kg ha^{-1} in weedy check (Table 1) This shows that weed biomass decreased with imposing tillage. Perhaps, tillage destroyed the existing weed flora and prevented the germination of the small seeded weeds by burying them deep. Therefore, the intensity of weeds was less in the tilled plots compared to no-till. These results for the tillage effects are in line with the findings of Tangadulratana (1985) that weeds tended to be minimum when tillage was imposed and conventional tillage was superior to no-tillage regarding weed infestation. Similarly, Elliot *et al.*, (1993) reported that by increasing the number of plowing and harrowing weed biomass and time required for weeding were reduced. They further noted that grassy weeds were more under zero tillage compared to conventional tillage plots. Kamau *et al.,* (1999) reported that tillage reduced fresh weed biomass. Lower fresh weed biomass at higher plant population indicated that increasing plant population ensured uniform crop stand and covered the open niches which otherwise might have been utilized by weeds. So, with increasing plant population, the chances of weed establishment were minimized. These results are in agreement with the work of Tollenaar *et al.,* (1994) that increasing plant density reduced weed biomass. Due to the effective weed control hand weeding and black plastic mulch recorded least weed biomass. The weeds in the hand weeding were destroyed through weeding twice, while the weeds under black plastic mulch might have failed to germinate due to lack of light and rise in temperature under black plastic. These results are in line with the findings of Syawal (1998) and Khan *et al.,* (1998) who reported that hand weeding effectively controlled weeds. While Unger & Ackermann (1992) reported that cover crops reduced weed biomass by 41, 62 and 94 %, respectively.

Biological yield: The effect of tillage practices, plant populations and mulches was significant on biological yield of maize, while among the interactions tillage x mulches and populations x mulches were significant (Table 1). Conventional tillage recorded higher biological yield (7980 kg ha^{-1}) compared to zero-tillage (7708 kg ha^{-1}), while increasing plant population increased biological yield linearly. Similarly, maximum biological yield was recorded in the hand weeding (9118 kg ha^{-1}) and black plastic mulch (8982 kg ha^{-1}), followed by weeds mulch (7956 kg ha^{-1}) and white plastic mulch (7934 kg ha^{-1}) and followed by living mulch (7540 kg ha^{-1}) compared to 5537 kg ha^{-1} in weedy check (Table 1). Higher leaf area and lower fresh weed biomass in conventional tillage might have contributed to higher biological yield in conventional tillage as compared to zero tillage. These results are in agreement with the work of Karunatilake *et al.*, (2000) who reported higher stem and root biomass in tilled plots as compared to zero tillage. Increase in biological yield at higher plant population might be due to increase in number of plants as well as in plant height of individual plants at denser populations. The results of Hashemi *et al*., (2005) strongly supported our findings who reported the highest biological yield from 90000 plants ha^{-1}. Ammanullah *et al.* (2009) also reported higher biological yield at higher plant populations. The highest biological yield in the hand weeding and black plastic mulch might be attributed to their maximum plant height and leaf area as a result of their efficient weed control. These results are in line with the work of Kwabiah (2003) that maximum biological yield was recorded in the plastic mulch, while Nawab *et al.,* (1997) reported that hand weeding significantly increased biological yield.

The effect of tillage, plant populations and mulches was significant on fresh weed biomass, leaf area of maize $plant^{-1}$, leaf area index and biological yield. Zero tillage increased fresh weed biomass while affected leaf area, leaf area index and biological yield negatively as compared to conventional tillage. This may explain the lower biological yield in the zero tillage. Similarly, higher biological under conventional tillage conditions might be attributed to the lower fresh weed biomass. Plant populations significantly affected fresh weed biomass, leaf area, leaf area index and biological yield. Lower fresh weed biomass, maximum leaf area $plant^{-1}$ and plant height might have contributed to higher biological yield in the higher plant populations. Mulches significantly affected all the studied parameters. Increased biological yield in the hand weeding and black plastic mulch might be attributed to increase in plant height, maximum leaf area and leaf area index as well as lower fresh weed biomass.

Table 1. Leaf area (cm^2), leaf area index, fresh weed biomass (kg ha^{-1}), weed species composition and biological yield (kg ha^{-1}) of maize as affected by tillage, plant population and mulches during 2006 and 2007.

Factor	Level	Leaf area of maize $plant^{-1}$ (cm^2)	Leaf area index of maize	Fresh weed biomass (kg ha^{-1})	Biological yield (kg ha^{-1})
		2006-07	2006-07	2006-07	2006-07
Tillage	Zero	4094*	2.39*	183*	7708*
	Conventional	4722	2.84	165	7980
Populations	90000 plants ha^{-1}	3894c	3.57a	158c	8541a
	60000 plants ha^{-1}	4398b	2.73b	168b	7992b
	30000 plants ha^{-1}	4932a	1.55c	196a	7000c
	LSD	**86**	**0.049**	**8.5**	**125.5**
Treatments	Weeds mulch	4432b	2.62b	164c	7956b
	Black plastic	4844a	2.87a	120d	8982a
	White plastic	4426b	2.63b	191b	7934b
	Living mulch	4360b	2.59b	195b	7540c
	Hand weeding	4848a	2.88a	112d	9118a
	Weedy check	3537c	2.11c	260a	5537d
	LSD	**105**	**0.06**	**10.4**	**154**
Interactions	Tillage x Population	*	*	NS	NS
	Tillage x Mulches	*	*	NS	*
	Population x Mulches	*	*	*	*
	Tillage x Population x Mulches	*	*	NS	NS

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

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