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Effect of Maize (*Zea mays* L.) and Legume Intercropping Systems on Weed Dynamics

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Abstract

The field experiments were conducted during two consecutive seasons of *kharif* (June to October), 2016 and 2017 at the Experimental Research Farm, ICAR Research Complex for NEH Region, Nagaland Centre, Medziphema, Nagaland, India. The treatments consisted of four planting geometries i.e. maize+black gram (1:1), maize+black gram (2:2), maize+soybean (1:1) and maize+soybean (2:2) and three weed management practices i.e. weedy check, pre-emergence application of pendimethalin @ 1.0 kg a.i. ha^{-1}+one hand weeding (1HW) at 30 DAS and two hand weedings (2HW) at 20 and 40 DAS. The experiment was laid out in Randomized Block Design with two factors comprising twelve treatment combinations and replicated three times. The results revealed that among the planting geometry, maize+soybean (2:2) recorded the highest weed control efficiency (WCE) and reduced the weed population, fresh weight and dry weight of monocot and dicot weed at 60 DAS and gave the maximum maize equivalent yield (4374.96 kg ha^{-1}). Among the weed management, 2HW at 20 and 40 DAS recorded the lowest weed population, fresh weight, dry weight and the highest weed control efficiency (WCE) of monocot and dicot weed at 60 DAS and the maximum maize equivalent yield as 4591.10 kg ha^{-1} which was at par with the pre-emergence application of pendimethalin @ 1.0 kg a.i. ha^{-1}+1HW at 30 DAS as 4461.80 kg ha^{-1}. The highest net return (₹ ha^{-1}), return per rupee invested and B:C ratio were recorded from the pre-emergence application of pendimethalin @ 1.0 kg a.i. ha^{-1}+1HW at 30 DAS with ₹ 36624.05 ha^{-1} which was closely followed by 2HW at 20 and 40 DAS with ₹ 35428.81 ha^{-1}.

Keywords: Black gram, economics, maize, planting geometry, soybean, weed, yield

1. Introduction

Maize (*Zea mays* L.) is a versatile crop which can adapt under varied agro-climatic conditions. After rice and wheat, it is the third most important food crop in India. It is used as human food 23%, poultry feed 51%, animal feed 12%, industrial (starch) products 12%, beverages and seed 1% each. In India, it was estimated that the area, production and productivity of maize during the year 2017–2018 was 9.38 mha, 28.75 mt and 3,065.00 kg ha^{-1} respectively (Anonymous, 2019). In NEH Region, it was estimated that the area, production and productivity of maize during the year 2017–2018 was 209.96 thousand ha, 386.79 thousand

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tonne and 1840.00 kg ha^{-1} respectively (Anonymous, 2018a). In Nagaland, it was estimated that the area, production and productivity of maize during the year 2017–2018 was 69.01 thousand ha, 136.78 thousand tonne and 1982.00 kg ha^{-1} respectively (Anonymous, 2018b).

Intercropping is defined as an agricultural practice of cultivating two or more crops in the same space at the same time (Andrew and Kassam, 1976). The reason for growing two or more crops together is to increase the production per unit land area per unit time. In intercropping system, all the environmental resources are utilized to maximize crop productivity. Intercropping of cereals with legumes is a recognized practice for economizing the use of nitrogenous fertilizer and increasing the productivity and profitability per unit area and time (Willey, 1979).

Crop weed competition was one of the major constraints in productivity of any crop and as such it interfered the successful crop production. The low productivity of maize in India as compared to world productivity can be attributed to several limiting factors and all but the most important amongst these has been the poor weed management which poses a major threat to crop productivity (Upasani et al., 2017). The major yield reducing factors for maize cultivation in India are weeds (Gharde et al., 2018). The critical period of crop weed competition was the period from the time of sowing upto which the crop was to maintain in a weed free environment to get higher yield. Weed management in intercropping system needed concentrated scientific efforts to provide weed free environment to both crop components. Weed control practices in maize resulted in 65 to 90% higher yield than unweeded (Barla et al., 2016; Kumawat et al., 2019). Wider row spacing in maize could be used to grow short duration legumes which would not only act as smoother crop but also would give additional yield. Weed management approach involving intercropping, herbicides and non- chemical methods in maize and maize based intercropping system was very important to provide effective and acceptable weed control for realizing high production. As weed management was considered as one of the important factors in the cereal+legume intercropping system for increasing productivity under rainfed agriculture, a search for the suitable cereal+legume intercropping system with appropriate weed management practice in rainfed agriculture has now become the need of the hour under the agro-physiographical conditions of N.E.H. region particularly of Nagaland.

2. Materials and Methods

The field experiments were conducted at the Experimental Research Farm of ICAR Research Complex for NEH Region, Nagaland Centre, Medziphema, Nagaland, India during two consecutive *kharif* seasons (June-October) of 2016 and 2017. The experimental site is situated at 25°45'24" N latitude and 93°50'27" E longitude at an altitude of 295 m above MSL. The treatments consisted of four planting geometry i.e. maize+black gram (1:1), maize+black gram (2:2), maize+soybean (1:1) and maize+soybean (2:2) and three weed management practices i.e. weedy check, pre-emergence application of pendimethalin @ 1.0 kg a.i. ha^{-1}+1HW (Hand weeding) at 30 DAS (Days after sowing) and 2HW at 20 and 40 DAS. The experiment was laid out in the Randomized Block Design with two factors (planting geometry and weed management) comprising twelve treatment combinations and replicated three times. The number of monocot and dicot weeds m^{-2} were counted by using a quadrate of 1 m^{-2} from each plot. Weeds found within the quadrate were removed and recorded the fresh weight with the help of electronic/digital balance. The weeds were sun dried and thereafter transferred to a hot air oven at 65±5°C for 48 hours till a constant weight is obtained. Further, the weed dry weight was measured.

3. Results and Discussion

3.1. Effect on weeds

The most dominant weeds available in the experimental plots were monocot weeds like *Digitaria caliaris, Cyperus iria, Fimbristylis miliacea, Elueusine indica, Cynodon dactylon* and *Murdannia nudiflora* and dicot weeds like *Ageratum conyzoides, Lindernia ciliata, Lindernia crustacean, Mollugo pentaphylla, Leucus aspera* and *Eupatorium odoratum*. The data clearly revealed that planting geometry had a significant effect on weed population, fresh weight and dry weight of monocot and dicot weeds at 60 DAS. Planting geometry with maize+soybean (2:2) reduced the weed population, fresh weight, dry weight and the highest weed control efficiency of monocot and dicot weed which was statistically at par with maize+black gram (2:2) at 60 DAS. This might be due to relatively less space available for the growth of weeds due to quick coverage of ground and more shading effect by maize and soybean/black gram intercropping. Similar effects due to planting geometry were also reported by Prasad and Rafey (1996), Deshveer and Singh (2002) and Kithan and Longkumer (2016) (Table 1).

All the weed management practices had a significant effect over a weedy check at 60 DAS. 2HW at 20 and 40 DAS recorded the lowest weed population, fresh weight, dry weight and the highest weed control efficiency of monocot and dicot weed which was at par with pre-emergence application of pendimethalin @ 1.0 kg a.i. ha^{-1}+1HW at 30 DAS. Markable lower in weed population, fresh weight and dry weight of monocot and dicot weed due to 2HW at 20 and 40 DAS and pre-emergence application of pendimethalin @ 1.0 kg a.i. ha^{-1}+1HW at 30 DAS might be probably due to better weed control in critical stages of crop growth through hand weeding and phytotoxic effect of chemicals on a broad spectrum of weeds resulting in death of most of the weeds. Stanzen et al. (2016) and Swetha et al. (2018) were reported that the minimum density of weeds and biomass was observed under hand weeding at 20 and 40 DAS. The highest weed index

Table 1: Effect of planting geometry and weed management practices on number of weeds, weeds fresh weight and weeds dry weight at 60 DAS in maize based intercropping system (pooled data of two years)

Treatments	No. of weeds m^{-2}		Weeds fresh weight (g m^{-2})		Weeds dry weight (g m^{-2})		Weed control efficiency (WCE) (%)		Weed index (WI) (%)
	Monocot	Dicot	Monocot	Dicot	Monocot	Dicot	Monocot	Dicot	
Planting geometry									
Maize+black gram (1:1)	9.96 (114.99)	4.37 (20.73)	18.07 (381.03)	7.72 (66.52)	5.70 (36.93)	2.57 (6.74)	50.76	47.38	19.14
Maize+black gram (2:2)	9.13 (102.40)	4.12 (18.97)	16.36 (330.34)	7.13 (59.35)	5.23 (32.82)	2.43 (6.14)	56.24	52.07	12.14
Maize+soybean (1:1)	9.81 (112.22)	4.29 (20.12)	17.65 (363.94)	7.58 (64.34)	5.60 (35.94)	2.53 (6.54)	52.08	48.95	15.93
Maize+soybean (2:2)	8.82 (98.13)	3.97 (17.92)	15.67 (311.95)	6.90 (56.69)	5.06 (31.57)	2.35 (5.85)	57.92	54.33	10.01
SEm±	0.11	0.04	0.17	0.06	0.06	0.02			
CD (*p*=0.05)	0.31	0.11	0.49	0.18	0.18	0.06			
Weed management									
Weedy check	15.37 (235.93)	6.33 (39.66)	27.62 (764.32)	11.37 (129.01)	8.68 (75.01)	3.64 (12.81)	-	-	40.42
Pre-emergence application of pendimethalin @ 1.0 kg a.i. ha^{-1}+1HW at 30 DAS	7.15 (51.67)	3.29 (10.45)	12.88 (169.17)	5.59 (30.95)	4.14 (17.02)	1.98 (3.44)	77.31	73.15	2.51
2 HW at 20 and 40 DAS	5.78 (33.20)	2.94 (8.19)	10.30 (106.96)	5.04 (25.22)	3.37 (10.93)	1.78 (2.70)	85.43	78.92	-
SEm±	0.09	0.03	0.15	0.06	0.06	0.02			
CD (*p*=0.05)	0.27	0.09	0.43	0.16	0.16	0.05			

HW: Hand weeding; DAS: Days after sowing

(WI) was recorded under weedy check (40.42%). Maximum weed index with weedy check was due to competition offered by unchecked weed growth for nutrients, moisture and light as indicated by poor growth and lower yield. The lowest weed index was recorded pre-emergence application of pendimethalin @ 1.0 kg a.i. ha^{-1}+1HW at 30 DAS (2.51%). This might be due to improved growth as a consequence of effective control of weeds and reduction in the crop weed competition.

3.2. Effect on crop

3.2.1. Maize

The grain yield of maize was significantly different among planting geometry and weed management practices. The highest grain yield was recorded as 2565.96 kg ha^{-1} from maize+soybean (2:2) followed by maize+black gram (2:2) as 2505.12 kg ha^{-1}. The reason for maximum grain yield in paired row planting may be due to decreased competition between plants because of equivalent spatial arrangement of plants. Similar findings were also reported by Maitra et al. (2000). Among the weed management, the highest grain yield of maize was recorded in 2HW at 20 and 40 DAS with 2851.33 kg ha^{-1} which was statistically at par with the pre-emergence application of pendimethalin @ 1.0 kg a.i. ha^{-1}+1HW at 30 DAS. Swetha et al. (2018) reported that maximum grain yield in hand weeding at 20 and 40 DAS. Shekhawat *et al*. (2002) was of the opinion that the increase in maize grain yield might be due to reduced weed competition as well as the cumulative increase in growth characters due to favourable conditions created under weed free conditions.

Maize equivalent yield was significantly different among planting geometry and weed management practices. Maize+soybean (2:2) recorded the highest maize equivalent yield as 4374.96 kg ha^{-1} which was statistically at par with maize+soybean (1:1) as 4165.55 kg ha^{-1}. This increase in total production of maize with soybean intercropping was the result of additional yield of soybean as bonus by utilization of inter-row space of maize crops. Similar results were also reported by Padhi and Panigrahi (2006). Among weed management practices, the highest maize equivalent yield was recorded by 2HW at 20 and 40 DAS as 4591.10 kg ha^{-1} which was statistically

at par with pre-emergence application of pendimethalin @ 1.0 kg a.i. ha^{-1}+1HW at 30 DAS as 4461.80 kg ha^{-1}. The reason for increase in maize equivalent yield under 2HW at 20 and 40 DAS might be due to reduced crop-weed competition during critical phase of crop growth.

3.2.2. Black gram and soybean

Seed yield of black gram and soybean were not significantly influenced by different planting geometry. All weed management treatments significantly effected the seed yield of black gram and soybean as compared to weed check. Among weed management practices, the highest seed yield of black gram was recorded with 2HW at 20 and 40 DAS as 389.22 kg ha^{-1} which was at par with pre-emergence application pendimethalin @ 1.0 kg a.i. ha^{-1}+1HW at 30 DAS as 376.02 kg ha^{-1}. The highest grain yield recorded with 2HW at 20 and 40 DAS followed by pre-emergence application of pendimethalin @ 1.0 kg a.i. ha^{-1}+1HW at 30 DAS might be due to lesser crop-weed competition in these treatments as they control weeds effectively than other treatments. Such a similar result was also reported by Singh (2011) and Shekhawat et al. (2002) reported that weed free treatment resulted in maximum grain yield.

Among weed management treatments, the highest seed yield of soybean was recorded with 2HW at 20 and 40 DAS as 969.53 kg ha^{-1} which was at par with pre-emergence application of pendimethalin @ 1.0 kg a.i. ha^{-1}+1HW at 30 DAS as 937.79 kg ha^{-1} and the lowest grain yield was recorded in weedy check as 657.31 kg ha^{-1}. The higher grain yield in these treatments might be due to the effective control of weeds during the early stages of crop growth that helped in better development of the plant through less competition for nutrients, radiation and water from weeds. Similar results were reported by Rao *et al*. (1995), Pandya et al. (2006).

3.3. Economics

The highest net return (₹ ha^{-1}), return per rupee invested and B: C ratio were recorded as ₹ 34802.52 ha^{-1}, 2.31 and 1.31 respectively from the planting geometry of maize+soybean (2:2). The results are in close conformity with the findings of Shivay et al. (2001), Padhi and Panigrahi (2006), Kaushal et al. (2015), Kithan and Longkumer (2016) and Panwar et al. (2016).

Among the weed management treatments the net return (₹ ha^{-1}), return per rupee invested and B: C ratio were recorded from pre-emergence application of pendimethalin@ 1.0 kg a.i. ha^{-1}+1HW at 30 DAS with ₹ 36624.05 ha^{-1}, 2.43 and 1.43 which was closely followed by 2HW at 20 and 40 DAS with ₹ 35428.81 ha^{-1}, 2.24 and 1.24. Pandey et al. (2001) concluded that the chemical control of weeds is more economical than hand weeding. The minimum net return was recorded in weedy check as ₹ 18636.54 ha^{-1} in the present experiments (Table 2).

Table 2: Effect of planting geometry and weed management practices on grain yield of maize, black gram and soybean, maize equivalent yield and economics in maize based intercropping system (pooled data of two years)

Treatments	Grain yield kg ha^{-1}			Maize equivalent yield kg ha^{-1} (MEY)	Economics (₹ ha^{-1})		
	Maize	Black gram	Soybean		Net return (₹ ha^{-1})	Return rupee^{-1} (₹)	B:C Ratio
Planting geometry							
Maize+black gram (1:1)	2305.60	351.82	-	3617.05	25551.54	2.01	1.01
Maize+black gram (2:2)	2505.12	358.52	-	3841.52	28682.91	2.14	1.14
Maize+soybean (1:1)	2396.93	-	845.22	4165.55	31882.21	2.20	1.20
Maize+soybean (2:2)	2565.96	-	864.53	4374.96	34802.52	2.31	1.31
SEm±	14.84	3.20	5.33	15.95			
CD (*p*=0.05)	42.31	NS	NS	45.45			
Weed management							
Weedy check	1699.05	300.28	657.31	2946.41	18636.54	1.83	0.83
Pre-emergence application of pendimethalin @ 1.0 kg a.i. ha^{-1}+1HW at 30 DAS	2779.83	376.02	937.79	4461.80	36624.05	2.43	1.43
2 HW at 20 and 40 DAS	2851.33	389.22	969.53	4591.10	35428.81	2.24	1.24
SEm±	12.85	3.92	6.52	13.81			
CD (*p*=0.05)	36.64	11.55	19.24	39.36			

HW: Hand weeding; DAS: Days after sowing

4. Conclusion

Weed management practices, 2HW at 20 and 40 DAS and pre-emergence application of pendimethalin @ 1.0 kg a.i. ha^{-1}+1HW at 30 DAS were recorded the lowest weed population, fresh weight, dry weight and the highest weed control efficiency of monocot and dicot weed and equally effective in increasing maize equivalent yield. However, pre-emergence application of pendimethalin @ 1.0 kg a.i. ha^{-1}+1HW at 30 DAS found most profitable in maize based intercropping with soybean.

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