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Research Paper

Modification of crop ecology in maize (*Zea mays*) through fertility levels and weed control measures under temperate conditions of Kashmir

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ABSTRACT

A field experiment was conducted during *kharif* seasons of 2008 and 2009 at Sher-e-Kashmir University of Agricultural Sciences and Technology Kashmir to study the effect of fertility levels, mulching and weed management practices on the microclimate of crop, soil temperature, phenological changes and yield of maize (*Zea mays* L.). The experiment was conducted in a split-plot design with three replications and consisted of four treatments *viz;* N_{90}, N_{90} + *Azotobacter*, N_{120}, and N_{120} + *Azotobacter* in main plots and five treatments *viz;* polyethylene mulch, straw mulch @ 1.0 tonne/ha, hand weeding at 30 and 60 DAS, atrazine @1.0 kg a.i./ha and weedy check in sub-plots. Results revealed that N_{90} + *Azotobacter* produced grain yields at par with N_{120}, resulting in saving of 30 kg N/ ha. Highest grain yield 5.14 t/ha, stover and biological yield with concomitant increase in yield attributes *viz;* number of cobs/plant, number of rows/cob, number of grains/row, cob length, cob diameter, 1,000-grains weight was obtained with polyethylene mulch. Polyethylene mulch also helped plants to reach phenological stages two to four days earlier as compared to unweeded check. Percentage of light interception by crop at the middle of the canopy was maximum with N_{120} + *Azotobacter*, more than other fertility levels. However, N_{90} treatment recorded the highest percentage of light interception among all the fertility levels, when recorded at the bottom of the canopy. Light interception was most with polyethylene mulch among all the weed control treatments when recorded at the middle of the canopy, whereas it was most with weedy check treatment when recorded at the bottom of the canopy. The peak values for the interception of radiation were observed at 90 DAS. The soil temperature in the polyethylene mulched plots was 6–8^{0}C higher as compared to un-mulched plots. Modification of crop ecology through polyethylene mulch and straw mulch resulted in 73.4% and 72.6% more grain yield, respectively, as compared to uncontrolled weedy check. Benefit cost ratio was the highest with N_{120} + *Azotobacter* and atrazine @ 1.0 kg/ha, respectively.

***Key words** : Azotobacter*, Crop ecology, Maize, Mulch, Polyethylene

Maize is an important cereal crops of India. It is cultivated over an area of 8.49 mha with a production and productivity of 21.29 mt and 2.51 t/ha. It caters the needs of both humans and animals by providing food and feed to them. It is a miracle crop because of its high yield potential and is also known as the queen of cereals. In Jammu and Kashmir State, the total area under this crop is 0.33 mha with a production of 0.525 mt (Sharma, 2007). The per hectare yield of this crop is low in Jammu and Kashmir State as compared to rice and wheat mainly because of poor nutrient and weed and weather abbrerations. The abundant rainfall in *kharif* season favours rapid weed growth. Weeds emerge with the germination of maize seeds and grow along with plants till the early growth period causing severe crop weed competition and cause a heavy drain of plant nutrients. The competition for growth factors in favour of crop can be exploited either with an increase in dose of nitrogen or effective control of weeds through crop ecology modification before the start of critical crop–weed competition. Unchecked weed growth in this crop may result in grain yield loss to the extent of 100% (Sharma, 2005). Keeping in view the above facts the present investigation was undertaken to study crop ecology modification of maize through fertilizer application and weed control measures.

MATERIALS AND METHODS

A field experiment was undertaken for two consecutive years of 2008 and 2009 at the experimental farm at S.K. University of Agricultural Sciences and Technology of Kashmir. The experiment in both the years consisted of

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four treatments *viz.*, N_{90} (F1), N_{90} + *Azotobacter* (F2), N_{120} (F3) and N_{120} + *Azotobacter* (F4) as main plots and five treatments *viz.*, weedy check (W1), atrazine @ 1.0 kg/ha (W2), hand weeding at 30 and 60 DAS (W3), straw mulch @ 1.0 tonne/ha (W4) and polyethylene mulch (W5), as sub-plots in a split-plot design with three replications. The soil of the experimental field was silty clay loam in texture, neutral in reaction with a pH of 6.7, low in available nitrogen (253.0 kg/ha) and medium in available phosphorus (13.83 kg/ha) and potassium (223.3 kg/ha). The mean maximum temperature ranged from 25.3 to 32.5 ^oC and minimum from 8.1 to 17.6 ^oC in 2008 and 20.2 to 33.2 ^oC and 8.1 to 19.8 ^oC in 2009. The total rainfall received during the entire growing season of 2008 and 2009 amounted to 203 mm and 362 mm, respectively. Maize variety C-6 was sown in rows at 60 cm apart with plant to plant distance of 20 cm using 20 kg seed/ha in the second week of May. A uniform dose of 60 kg P_2O_5/ha, 40 kg K_2O/ha and through diamonium phosphate and muriate of potash, $ZnSO_4$ @ 20 kg/ha was applied to each plot. Full dose of phosphorus, potassium and zinc and half dose of nitrogen as per treatment was applied as basal. The remaining half dose of nitrogen was applied in two equal splits at knee high and tasseling stage as per treatment. Seed dressing by biofertilizer (*Azotobacter* @ 0.5–0.8 kg/ha) was done at the time of sowing. Soil temperature, crop growth and development were modified by using different mulch materials. The soil temperature of the plots covered with polyethylene and straw mulches were recorded at alternate days through the soil installed thermometers up to 45 days after sowing. Light interception by crop and weed at 30 days interval at various canopy depths along with leaf area index at various growth stages were recorded by the canopy analyzer, Accupar L-80 (Decagon Devices USA).

RESULTS AND DISCUSSION

Effect of fertility levels

Plant height, dry matter accumulation (DMA) and leaf area index (LAI) of maize recorded at harvest of crop was more at higher fertility levels (N_{120}+*Azotobacter*) than at lower fertility levels (N_{90}) (Table 1). The increase in dry matter at higher fertility levels of the crop may be attributed to the increase in leaf area index and plant height, which resulted in better light interception and accumulation of more photosynthates, thus produced more dry matter. Application of higher quantity of nitrogen favoured rapid growth and enlargement of tissues resulting in higher leaf area index. Devi (2002) and Shanti *et al*. (1997) has also reported increased dry matter and leaf area index of maize with increased nitrogen levels. The number of days taken to attain physiological maturity differed significantly among all the fertility levels. Significantly more days were taken by the maize crop to maturity at the higher fertility level of N_{120} + *Azotobacter* followed by N_{120} , N_{90} + *Aotobacter* and N_{90}, respectively. Silking was approximately two days earlier with treatment N_{120} + *Azotobacter* than the treatment of N_{90} during both the years and the same was observed with increase in nitrogen level from N_{90} to N_{120} and N_{90} + *Azotobacter* to N_{120} + *Azotobacter*. Improved vegetative parameters (plant height, leaf area index and dry matter accumulation) favoured early initiation of reproductive phase, which helped in the advancement of silking at higher fertility level. These results are in accordance with Shanti *et al*., 1997. Higher fertility

Table 1. Effect of fertility levels and weed control measures on growth parameters at silking and harvest and grain yield of maize (Mean of two years)

Treatment	Plant height at harvest (cm)		LAI at harvest		DMA (t/ha) at harvest		Days to silking	
	2008	2009	2008	2009	2008	2009	2008	2009
Fertility level								
N_{90}	128	125	3.70	3.86	12.1	11.9	76.1	77.5
N_{90} + *Azotobacter*	131	128	3.85	3.96	13.6	13.2	75.4	77.0
N_{120}	133	131	3.98	4.16	13.9	13.7	75.1	76.3
N_{120} + *Azotobacter*	135	135	4.12	4.38	14.1	13.6	74.3	75.5
SEm±	4.0	2.9	0.13	0.16	0.37	0.26	0.33	0.40
CD (P=0.05)	NS	8.2	NS	NS	1.29	0.91	1.12	1.38
Weed control measure								
Weedy check	94	92	3.19	3.25	6.17	5.5	78.8	79.3
Atrazine @ 1.0 kg/ha	130	129	3.57	3.94	13.7	13.7	76.3	77.8
Hand weeding at 30 and 60 DAS	136	133	3.97	4.14	15.1	15.0	74.7	76.2
Straw mulch	144	144	4.23	4.40	15.8	15.5	73.7	75.3
Polyethylene mulch	154	151	4.59	4.72	16.4	15.8	72.8	74.3
SEm±	3.0	3.5	0.09	0.11	0.41	0.29	0.44	0.32
CD (P=0.05)	9.1	10.8	0.26	0.32	1.19	0.83	1.22	0.93

level treatment N_{120} recorded significantly higher grain yield; 20.76% with higher yield attributing characters, stover and biological yields than lower fertility level of N_{90} treatment (Table 1 and 2). *Azotobacter* along with 90 kg N/ha recorded grain yield, which was at par with 120 kg N/ha, thus resulting in a saving of 30 kg N/ha. Saving of 10–30 kg N/ha with increased grain yield and reduced depletion of soil nitrogen in maize has also been reported by Sonoria (2001). No significant increase in grain yield was observed at 120 kg N and 120 kg N + *Azotobacter* over N_{90} + *Azotobacter*. Increased grain yield of maize by the inoculation of biofertilizers has also been reported by Mishra *et al.,* 1998. The periodic data on light interception (%) recorded at 60 and 90 DAS and at maturity of maize crop at the middle of the canopy revealed that radiation interception increased with increase in crop age and reached maximum at 90 DAS and declined towards maturity in all the fertility treatments during both the years (Table 3). Higher fertility levels of N_{120} and N_{120} + *Azotobacter* recorded higher values of light interception by mid canopy than the lower fertility level (N_{90}) during both the years. It may be attributed to higher LAI values with higher fertility levels. These results are in conformity with that of Chahal *et al.* (1994). The efficiency of a treatment is finally decided in terms of the economics (benefit:cost ratio) of that treatment. The present investigation revealed that highest benefit:cost ratio alongwith gross and net returns was recorded with N_{120} + *azotobacter* (1.14) among fertility levels. Significant variation in soil temperature was observed at higher fertility level of N_{120} + *Azotobacter* than N_{90} and can be attributed to less crop weed competition and increased radiation load at higher fertility levels towards the lower layers of soil. Light interception recorded by crop and weed at the bottom of the canopy exhibited increased light interception (%) at the lower levels of nitrogen at the bottom of canopy of crop and weed during both the years. Maximum values were recorded with the N_{90} treatment than the N_{120} + *Azotobacter* treatment with peak values at the 90 days after sowing of the crop (Table 3). The graded levels of fertility showed declined trend of light interception towards maturity.

Effect of weed control measures

Among the weed control measures, weedy check recorded significantly lowest plant height, dry matter accumulation (DMA) and leaf area index (LAI) than rest of the treatments at harvest of the crop during both the years. Similar findings were reported by Kumar and Walia (2003). Polyethylene mulch recorded highest values of LAI at harvest with superiority of 5.99 and 3.84, 9.74 and 4.23, 18.73 and 11.5 per cent over straw mulch, hand weeding at 30 and 60 DAS and atrazine @ 1.0 kg/ha treat-

Table 2. Effect of fertility levels and weed control measures on the yield attributes, grain and biological yields and economics of maize (mean of two years)

Treatment	Cob length (cm)	Cob diameter (cm)	No. of cobs/ plant	No. of grains/ cob	1,000-grains weight (g)	Grain yield (t/ha)	Biological yield (t/ha)	Net returns ($\times 10^3$/ha)	*B:C ratio
Fertility level									
N_{90}	10.4	2.8	0.84	194	23.3	3.41	11.92	19.3	0.83
N_{90} + Azotobacter	11.1	2.9	1.00	215	24.0	4.05	13.42	26.1	1.13
N_{120}	13.9	3.2	1.11	240	24.5	4.30	13.71	27.1	1.20
N_{120} + Azotobacter	14.9	3.4	1.22	258	26.0	4.38	13.61	28.0	1.14
SEm±	0.23	0.13	0.04	5.0	0.6	0.12	0.36	-	-
CD (P=0.05)	0.80	0.37	0.14	16.0	2.07	0.39	1.27	-	-
Weed control measure									
Weedy check	9.8	2.4	0.59	182	20.9	1.37	5.75	17.2	0.09
Atrazine @ 1.0 kg/ha^{-1}	11.7	2.6	0.95	205	22.0	3.91	13.74	32.3	1.78
Hand Weeding at 30 and 60 DAS	12.4	3.0	1.13	234	23.7	4.77	14.99	35.2	1.61
Straw mulch	14.0	3.9	1.20	250	24.9	4.98	15.53	34.6	1.33
Polyethylene mulch	14.8	4.2	1.35	262	26.0	5.14	15.81	21.7	0.54
SEm±	0.36	0.15	0.06	2.0	0.40	0.10	0.39	-	-
CD (P=0.05)	1.05	0.44	0.19	9.0	1.09	0.29	1.12	-	-

**Cost of grain = ₹800/q ; Cost of stover: = ₹200/q ments respectively, during 2008 and 2009. Significantly higher leaf area index of crop was recorded in polyethylene mulch than hand weeding at 30 and 60 DAS treatment (Table 1) because of presence of weeds at earlier and later stages of crop growth under hand weeding treatment. Weedy check recorded significantly lowest grain yield than rest of the weed control treatments. Uncontrolled weedy check caused 73.41% reduction in grain yield of maize compared to polyethylene mulch treatment. Polyethylene mulch and straw mulch recorded higher percentage of light interception at the middle canopy than uncontrolled weedy check. It was due to the vigorous crop growth and more LAI in the treated plots than the weedy check treatment. Weedy check treatment recorded higher percentage of light interception at the bottom of canopy than the other weed control treatments during both the years (Table 3). With depth in plant canopy the radiation load decreased downward due to shading much more so in a weedy check treatment which block light penetration (Allen *et al.*, 1996). All the weed control measures recorded significantly fewer days to attain silking than the weedy check. Fewer days for silking were required by polyethylene mulch, which was at par with straw mulch, which was significantly lower than weedy check and atrazine @ 1.0 kg/ha during both the years. Early silking in weed control treatments was due to the rapid development of reproductive phase. Pandey *et al.*, (2002) and Tollenaar *et al.*, (2004) reported that silking was delayed by weed interference in maize. Economics of the crop revealed that atrazine @ 1.0 kg/ha exhibited the highest B:C ratio (1.78) among weed control measures though gross and net returns were the highest with polyethylene mulch and hand weeding at 30 and 60 DAS treatments respectively. The lowest B:C ratio was recorded with N_{90} and weedy check treatments, respectively (Table 2). Mandal *et al.*, (2004) reported the highest benefit:cost ratio with atrazine @ 1.0 kg/ha + one handing at 30 DAS. Maximum average soil temperature of ten days was 39.96 ^{0}C in polyethylene mulch, recorded at alternate days showed that the variation in soil temperature ranged from 4 to 10 ^{0}C among different weed control measures. Effective solar heating of soil by polyethylene mulch compared with other treatments

Table 3. Light interception (%) by crop and weed at the middle and bottom of the canopy at 30 days interval as affected by different fertility levels and weed control measures (Mean of two years)

Treatment	Light interception at the middle of canopy (%)			Light interception at the bottom of canopy (%)		
	60 DAS*	90 DAS*	Harvest	60 DAS*	90 DAS*	Harvest
Fertility level						
N_{90}	39.3	56.8	36.4	56.8	71.9	45.4
N_{90} + *Azotobacter*	41.5	59.2	37.7	55.5	69.7	43.7
N_{120}	44.5	61.1	38.3	54.5	68.1	42.6
N_{120} + *Azotobacter*	44.8	62.9	39.1	49.1	65.6	41.8
Weed control measure						
Weedy check	38.0	54.3	34.3	57.9	71.6	46.4
Atrazine @ 1.0 kg/ha	40.9	59.5	37.1	56.4	70.2	45.1
Hand weeding 30 and 60 DAS	42.4	52.8	38.4	54.8	69.1	43.1
Straw mulch	44.1	61.9	39.3	52.2	67.8	42.0
Polyethylene mulch	45.5	63.6	40.2	48.6	65.4	40.3

Table 4. Average soil temperature (^{0}C) at 5 cm depth as affected by different fertility levels and weed control measures

Treatment	First 0 to 10 days	10 to 20 days	20 to 30 days	30 to 40 days	40 to 45 days
Fertility level					
N_{90}	42.9	35.0	31.5	28.9	27.7
N_{90} + *Azotobacter*	42.7	39.6	31.7	28.7	27.2
N_{120}	42.4	41.2	37.3	28.8	27.0
N_{120} + *Azotobacter*	42.8	43.6	38.3	34.8	31.6
CD (P=0.05)	1.5	1.7	1.5	0.8	0.7
Weed control measure					
Weedy check	28.6	28.8	28.1	28.2	26.6
Atrazine @ 1.0 kg/ha	34.3	35.9	28.7	28.0	25.2
Hand weeding 30 and 60 DAS	34.5	36.8	29.8	28.2	25.8
Straw mulch	38.1	38.7	31.9	31.2	28.6
Polyethylene mulch	39.2	40.0	33.9	33.0	31.5
CD (P=0.05)	1.5	1.7	1.5	0.8	0.7

may be due to better transmittance of total solar radiation, but less transmission of long-wave radiation, which reduced the escape of heat from soil (Table 4). These results are in accord once with the findings of Meti and Hosmani (1994).

Application of nitrogen @ 90 kg N/ha along with *azotobacter* produced grain yield that was significantly at par with 120 kg N/ha, thus resulting in a saving of 30 kg N/ha. Among weed control measures, polyethylene mulch was the best for soil solarisation, advancement of phonological stages towards maturity, weed control, shifting of nutrients and higher yield of maize followed by straw mulch but was less economical because of heavy cost. Therefore, atrazine @ 1.0 kg/ha with one hand weeding at knee high stage is recommended for better weed control and higher profitability in maize.

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