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Effect of fertility levels and weed management practices on growth, economics and nutrient uptake of *Rabi* maize (*Zea mays* L)

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Abstract
A field experiment was conducted on maize during the *rabi* season of 2019-20 and 2020-21 at the Instructional Cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). The experiment laid out in split plot design with three replication. Three fertility levels *viz.* 75%, 100% and 125% RDF are assigned to main plot and eight weed management practices *viz.* W_1 - Atrazine 1000 g ha^{-1} as PE, W_2 - Tembotrione 120 g ha^{-1} as PoE, W_3 - Atrazine 750 g ha^{-1} as PE *fb* Tembotrione 90 g ha^{-1} as PoE, W_4 - Atrazine 750 g ha^{-1} as PE *fb* Metsulfuron-methyl 4.0 g ha^{-1} as PoE, W_5 - Straw mulch 5.0 ton ha^{-1} after emergence of crop, W_6 - Live mulch with green gram up to 45 days then incorporation, W_7 - Mechanical weeding (wheel hoe) at 20 and 40 DAS, W_8 - Weedy check were assigned to sub plot. The soil of the experimental field was clayey in texture (*Vertisols*) locally known as "*Kanhar*". The soil was neutral in reaction. The available nitrogen, phosphorus and potassium content were low, medium and high. Maize F_1 hybrid "DKC-9081" was taken as test crop during the course of investigations. It's a high yielding variety with robust and uniform cobs. Among fertility levels significantly higher grain yield (71.2 q ha^{-1}), stover yield (126.5 q ha^{-1}), gross returns (₹ 1, 35,218 ha^{-1}), net returns (₹ 1, 03,849 ha^{-1}) and benefit: cost ratio (3.31) were recorded with 125% RDF. Among weed management practices (W) *i.e.* (W_3) application of pre-emergence atrazine 750 g ha^{-1} at 3-5 DAS *fb* tembotrione 90 g ha^{-1} as PoE was found most effective against grassy and non-grassy weeds as compared to other weed management treatments, resulting into the higher grain yield (75.10 q ha^{-1}), stover yield (130.00 q ha^{-1}), gross returns (₹ 1,34,510 ha^{-1}), net returns (₹ 1,03,777 ha^{-1}) and benefit: cost ratio (3.38). Total uptake of nutrients for nitrogen, phosphorus and potassium (201.30, 71.00 and 200.50 kg ha^{-1}, respectively) was significantly higher under F_3 - 125% RDF and minimum total nutrient uptake by crop was observed under F_1 -75% RDF. The increased concentration and yields of grain and stover in above treatments enhanced the uptake of nutrients in maize. In case of weed management practices, total uptake by crop of nitrogen, phosphorus and potassium (187.1, 61.0 and 200.5 kg ha^{-1}, respectively) was significantly higher in (W_3) application of pre-emergence atrazine 750 g ha^{-1} at 3-5 DAS *fb* tembotrione 90 g ha^{-1} as post emergence and minimum uptake of nutrient by crop observed by (W_8) weedy check.

Keywords: Fertility levels-75%, 100% and 125% RDF, weed management practices, maize, economics and nutrient uptake

Introduction
Maize (*Zea mays* L.) referred as "miracle crop" or the "queen" of cereals is one of the most important crop of the world and third most important crop of India after rice and wheat. It occupies an area of 9.43 mha with production of 25.66 million tonnes (mt) and average productivity of 2580 kg/ha in the country (Anon., 2015) [1]. In Chhattisgarh, maize occupies an area of 102.70 thousand ha with annual production of about 185.80 thousand tonnes with average productivity of about 1809 kg ha^{-1} (Anonymous, 2015) [1]. By 2050, India would like to triple its maize production from the current levels and that too with limited natural resources under changing climate (Anon., 2015) [1]. The productivity of maize is tremendously lower than other maize growing counties of the world (5.16 t/ha) Maize holds potential for diversification and livelihood security as reported elsewhere (Das *et al.* 2012) [2]. There are many reasons for low productivity, among them mismanagement of plant nutrition and weed management is considered to be the major one. Hence, there is a need to evolve best nutrient and weed management strategies to enhance the maize production evolving region specific nutrient management and weed management strategies is highly essential. But, weeds pose a major problem in *rainy* as well as *rabi* season maize due to congenial growth conditions primarily because of frequent rains, wide spacing and initial slow growth often inflicting huge losses ranging from 28 to 100% (Das *et al*. 2012) [2].

Almost all types of weeds *viz.* grassy, broad-leaf weeds and sedges infest the maize fields. Atrazine as pre-emergence is the most widely used herbicide in maize. It effectively controls broad-leaf weeds but control of sedges and some grasses remains a problem particularly in situation of variable soil moisture coupled with labour scarcity restricting the intercultural operations. Hence, there is a need for some post-emergence herbicide (s) for broad-spectrum weed control in maize.

Materials and Methods

A field experiment control of mixed weed flora in maize was conducted during *rabi* seasons 2019-20 and 2020-21 at the Instructional Cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh). The soil of the experimental field was clayey in texture (*Vertisols*) locally known as "*Kanhar*". The soil was neutral in reaction. The available nitrogen, phosphorus and potassium content were low, medium and high. The experiment was laid out in split plot design with three replication. Three fertility levels *viz.* 75%, 100%, and 125% RDF are assigned to main plot and eight weed management practices *viz.* W_1- Atrazine 1000 g ha^{-1} as PE at 3-5 DAS, W_2- Tembotrione 120 g ha^{-1} at 2-4 leaf stage (25 DAS), W_3- Atrazine 750 g ha^{-1} as PE at 3-5 DAS *fb* tembotrione 90 g ha^{-1} as PoE at 2 - 4 leaf stage (25 DAS), W_4- Atrazine 750 g ha^{-1} as PE *fb* metsulfuron-methyl 4.0 g ha^{-1} as post emergence (25 DAS), W_5- Straw mulch 5 ton ha^{-1} after emergence of crop, W_6- Live mulch with green gram up to 45 days and incorporation, W_7- Mechanical weeding (wheel hoe) at 20 and 40 DAS, W_8- Weedy check were assigned to sub plot.

Recommended dose of fertilizer was 120:60:40 kg N, P_2O5 and K_2O kg ha^{-1}. Fifty per cent of N and entire dose of P and K was applied at the time of sowing in the form of urea single super phosphate and murate of potash, respectively based on nutrient combinations. Remaining 50 per cent N was top dressed at knee height stage at 30 days after sowing in the form of urea. The herbicides were sprayed with knapsack sprayer fitted with flat- fan nozzle using water volume of 500 l/ha. Tembotrione and metsulfuron-methyl was applied at 2-4 leaf stage of the weeds (25 DAS). During 20019-20 and 2020-21, maize hybrid "DKC-9081" was sown on 26th Nov. with a spacing of 60 x 20 cm using seed rate of 20 kg/ha. Sowing was done on north side of the east-west ridges by dibbling method followed by irrigation up to half ridge on the next day. Plot size was 6.0 x 4.2 m during both years. The data on weed density (number/m^{-2}) and dry weight of weeds was recorded from two randomly selected spots in each plot at 20, 40 and 60 days after sowing (DAS) using 0.5 × 0.5 m quadrat, respectively. The weeds of different species of weeds were uprooted at 20, 40 and 60 days after sowing. The weeds were placed in paper bag and were dried in an oven at 65 degree until the weeds attained a constant weight. Dried biomass was recorded as dry weight of weeds. The DMA of weeds expressed in g/m^{-2}. Observations on growth, yield attributes, kernel and stover yields were recorded as per the standard procedure. The data collected on weeds were subjected to square root transformation ($\sqrt{x+0.5}$) to meet assumption of variance for statistical analysis. Weed control efficiency (WCE) was calculated on the basis of data recorded at 20, 40 and 60 days after sowing, treatment as per the formula suggested by Mani *et al.* (1976) [8]. The data were subjected to ANOVA and means were separated at p=0.05 with Fishers' LSD test. Crop was raised according to package of practices of the maize. The data on growth, yield attributes and yield was recorded and subjected to statistical analysis. The economics of the system was worked out considering the prevailing cost of inputs and price of output. Maize grain and stover sample were collected, dried, powdered and used for estimating the N, P and K contents. The nitrogen content in the grain and stover was estimated by Micro Kjeldhal method (Jackson, 1967) [8] and expressed in percentage on dry weight basis. The phosphorus and potassium in the plant sample was digested in di-acid mixture (900 ml concentrated nitric acid 400 ml of perchloric acid) as described by Piper (1966) [19] and estimated by Vanadomolybdo phosphonic yellow colour method (Jackson. 1967) [8] and Flame Photometer Method (Jackson, 1967) [8], respectively. The plant uptake of nutrients was expressed in percentage on dry weight basis while the crop removal was calibrated using grain and stover yield were worked out.

Results and Discussion

Effect on weeds Weed flora of the field consisted of mainly *Echinochloa colona*, *Medicago denticulata*, *Chenopodium album*, *Alternanthera sessilis*, *Dinebra retroflexa*, *Cyperus iria* and *Euphorbia geniculata* were the most dominant weeds.

Amongst the different fertility levels, significant increase in weed density and dry matter of (broad and narrow-leaved weeds and sedges) weeds at 40 DAS was recorded by raising the fertility levels up to 125% RDF. The maximum density of 122.33 no. /m^{-2} and weed dry matter of 29.50 g/m^{-2} was recorded under 125% RDF and minimum density and weed dry matter was recorded under 75% RDF (68.17 no / m^{-2} and 15.27 g/m^{-2}). Significant increase in weed dry matter with increase in fertility levels might be ascribed to the fact that increasing fertility provides greater amount of nutrients to weeds which perhaps might have resulted into better growth of weeds and reflected into more dry matter accumulation by them. The observed relationship corroborate with the findings of Venkata *et al*. (2016) [15].

Amongst the weed managements practices, density of weed in Table 1, (grassy, broad-leaf weed and sedges) and dry weight of weeds decreased with the pre emergence application of atrazine (50% WP) 750 g ha^{-1} *fb* tembotrione 42% SC w/v (34.4% SC w/w) 90 g ha^{-1} as post emergence at 25 days after sowing. Atrazine 750 g ha^{-1} as 2-3 DAS *fb* tembotrione 90 g ha^{-1} as PoE at 2- 4 leaf stage was realized essential to attain its satisfactory efficacy; as the density and dry weight of weeds decreased significantly of grassy, BLW and sedges as compared to weedy check during both the years on the basis of pooled data. Maximum weed density and dry weight of weed was recorded in weedy check. The better weed control these treatments was because of these reason that pre and post emergence application of these herbicides curb the germination and growth of majority of weeds for longer possibly due to its longer persistence in soil. The results corroborated with the findings of Nadigar *et al.* (2013) [14] and Dutta *et al.* (2016) [13] in hybrid maize. It was also realized essential to achieve satisfactory weed control efficacy of tembotrione against mixed weed flora in maize earlier also (Singh *et al*. 2012) [4]. Tembotrione provided effective control of all type of weeds including *Cyperus spp.* with maximum efficacy at tembotrione 90 and 120 g/ha. Atrazine also provided good control of grassy and broad-leaf weeds during both the year but it was not effective against sedges. Efficacy of tembotrione 90 g/ha along with atrazine was found most effective against grassy and non-grassy weeds as compared to

other herbicides either applied as pre- or post-emergence (Singh *et al*. 2012) [4].

Grain and stover yield of maize

Among fertilizer levels significantly higher grain and stover yield was recorded with application of 125% RDF (71.2 and 126.5 q ha^{-1}, respectively) as compared to 75% RDF (48.4 and 86.0 q ha^{-1}, respectively) in Table 3. Maximum harvest index (39.3) and B: C ratio (3.31) was obtained under fertility levels of 125% RDF (F_3) whereas, lowest was observed in fertility levels of 75% RDF (F_1) during both the years on the basis two yeas pooled data. Higher fertility levels might have increased availability of nutrients in the soil which culminated into more absorption and higher uptake of nutrients by the crop thereby better plant growth. The favourable effect on yield could also be due to lesser competition for nutrient between crop and weeds under higher fertility levels. Results corroborate with the findings of Singh and Nepalia (2009) [17].

Among weed management practices, Application of atrazine 750 g ha^{-1} as PE at 3-5 DAS *fb* tembotrione 90 g ha^{-1} as PoE at 2-4 leaf stage at 25 DAS (W_3) provided the maximum grain and stover yield (75.10 q/ha and 130.0 q /ha during 2019-20 and 2020-21) on the basis of two year pooled data and was superior to all other weed management treatments (Table 3). However, grain and stover yield of maize under (W_4) atrazine 750 g ha^{-1} as PE *fb* metsulfuron-methyl 4.0 g ha^{-1} at 25 DAS as PoE (70.7 q ha^{-1} and 121.5 q /ha) was at par with (W_2) tembotrione 120 g ha^{-1} at 2-4 leaf stage (25 DAS) during both of the years. Pre-emergence application of atrazine 750 g ha^{-1} at 3-5 DAS *fb* tembotrione 90 g ha^{-1} as PoE at 2 - 4 leaf stage at 25 DAS (W_3) has been reported most effective against complex weed flora resulting into the highest grain yield of maize earlier also (Singh *et al*. 2012) [4], and the B: C ratio (3.38) was also highest under these treatment during both the years. Maximum harvest index was obtained under fertility levels of 125% RDF (F_3) whereas, lowest was observed in fertility levels of 75% RDF (F_1). Among the weed management practices was found highest weed control efficiency in W_3- Atrazine 750 g ha^{-1} as PE at 3-5 DAS *fb* Tembotrione 90 g ha^{-1} as PoE at 2-4 leaf stage. It might be due to successfully control of all type of weeds flora in the crop field during both the year.

Economics

Application of 125% RDF has recorded significantly higher gross and net returns (₹ 1,35,218 and ₹ 1,03,849 ha^{-1}, respectively) over application of 75% RDF and on par with 100% RDF with respect to gross and net returns (₹ 1,12,916 and ₹ 82,586). The variations in gross and net returns was attributed to variations in grain, stover yields and also cost of cultivation. Higher B: C of 3.31 was recorded with application of 125% RDF (Table 3). It might be due to high yields and less cost of cultivation. The results are in conformity with the findings of Pagad (2014) [6]. Among the weed managements practices (W) *i.e.* (W_3) application of pre-emergence atrazine 750 g ha^{-1} at 3-5 DAS *fb* tembotrione 90 g ha^{-1} as PoE was found most effective against grassy and non-grassy weeds as compared to other weed management treatments, resulting into the higher grain yield (75.10 q ha^{-1}), stover yield (130.00 q ha^{-1}), gross return (₹ 1,34,510 ha^{-1}), net return (₹ 1,03,777 ha^{-1}) and benefit: cost ratio (3.38). Interaction effect of fertility levels and weed management practices revealed that, combination of (F_3) 125% RDF along with (W_3) application of pre-emergence atrazine 750 g ha^{-1} as PE *fb* tembotrione 90 g ha^{-1} as post emergence at 2-4 leaf stage (25 DAS) has recorded higher grain yield (88.33 q ha^{-1}), stover yield (153.93 q ha^{-1}), gross returns (₹ 1,58,994 ha^{-1}), net returns (₹ 1,22,780 ha^{-1}) on mean basis of pooled data during both years.

Nutrient uptake

Increased yield and growth attributes might be interpreted as the manifestation of higher nutrient uptake by the plants. Nutrient uptake per hectare increased linearly as the fertilizer level increased (Table 2). The nutrient uptake is a function of biomass and nutrient concentration in plant. Significantly higher uptake of nitrogen (201.3 kg ha^{-1}), phosphorus (71.0 kg ha^{-1}) and potassium (200.5 kg ha^{-1}) was recorded with 125 per cent RDF as compared to 75 per cent fertility levels on the basis of pooled data of two year. The nutrient uptake by the crops is mainly the function of crop yield. Therefore, considerable increase in N, P and K uptake by crop was attributed to higher grain and stover yield at higher fertility levels. The results are in close conformity with the findings of Nath *et al.* (2009) [16] and Parvati Deewan *et al.* (2018) [10] in maize.

All the weed management treatments significantly enhanced N and P uptake by grain, stover as well as total uptake of these nutrients by the crop over weedy check (Table 2). Significantly higher nutrient uptake was noticed in weed management practices at (W_3) atrazine 750 g ha^{-1} as PE at 3-5 DAS *fb* tembotrione 90 g ha^{-1} as PoE at 2 - 4 leaf stage at 25 DAS (187.1, 61.0 and 178.8 kg N, P and K ha^{-1}, respectively). Ullasa *et al*. (2016) [9] opined that weed management of nutrients promotes root absorption of the same nutrients or other nutrient there by improves root growth and nutrient movement from terminal leaves to roots and enhance the nutrient uptake which in turn enhances efficient use of applied nutrients. Weed management practices, it increases the nutrients uptake from the soil and helped in timely availability of nutrient in sufficient quantity to the plants. The better absorption, assimilation and translocation of applied nutrients lead to more uptake of nutrients which in turn resulted in higher dry matter production.

In case of interaction higher amount of nutrient uptake was recorded with the application of 125 per cent RDF along with weed management at F_3W_3 (218.72, 78.11 and 4219.61 kg N, P and K ha^{-1}, respectively). This could be due cumulative positive effect of both higher fertility levels and atrazine 750 g ha^{-1} as PE at 3-5 DAS *fb* Tembotrione 90 g ha^{-1} as PoE at 2 - 4 leaf stage (25 DAS). These results are in accordance with those obtained by Parvati Deewan *et al*. (2018) [10], Manja Naik (2012) [11] and Chaithanya (2015) [12].

Table 1: Weed count, weed dry matter, and weed control efficiency as influenced by different fertility levels and weed management practices at 40 days after herbicide application. (Pooled data of two years)

Treatments	Weed density (no. /m^{-2})	Dry weight of weeds (g/ m^{-2})	Weed control efficiency (%)
Fertility Levels (F)			
F_1:75 % RDF	7.91 (68.17)	4.38(15.27)	48.30
F_2:100 % RDF	9.16 (90.46)	5.20 (21.37)	27.41
F_3:125 % RDF	10.70 (122.33)	6.11 (29.50)	0.00
SEm±	0.05	0.03	-
C D (P=0.05)	0.19	0.11	-
Weed Management (W)			
W1	8.29 (69.00)	4.67 (16.00)	70.99
W2	8.14 (66.89)	4.58 (13.40)	72.10
W3	6.35 (40.22)	3.63 (9.86)	83.03
W4	7.80 (62.00)	4.38 (12.63)	74.46
W5	7.97 (64.22)	4.47 (15.13)	73.52
W6	8.30 (71.00)	4.66 (16.84)	71.08
W7	12.46 (156.44)	7.00 (36.82)	33.91
W8	14.75 (219.44)	8.45 (55.68)	0.00
SEm±	0.09	0.07	-
C D (P=0.05)	0.27	0.19	-
Interaction (FxW)	S	S	-

*Original figures in parentheses were subjected to square root transformation (√x+0.5) before statistical analysis;

Abbreviations

F_1- 75% RDF	F_2- 100% RDF	F_3- 125% RDF	DAS, days after sowing
W_1- Atrazine 1000 g ha^{-1} as PE			W_2- Tembotrione 120 g ha^{-1} at 2-4 leaf stage
W_3- Atrazine 750 g ha^{-1} as PE *fb* Tembotrione 90 g ha^{-1} as PoE at 2 - 4 leaf stage			
W_4- Atrazine 750 g ha^{-1} PE *fb* Metsulfuron-methyl 4.0 g ha^{-1} at PoE			
W_5- Straw mulch 5 ton ha^{-1} after emergence of crop			W_6- Live mulch with green gram up to 45 days then incorporation
W_7- Mechanical weeding (wheel hoe) at 20 and 40 DAS			W_8- Weedy check (Unweeded check)

Table 2: Nutrient uptake at harvest stage by maize crop as influenced by fertilizer levels and weed management practices (Pooled data of two years)

Treatments	Nutrient uptake by maize (kg ha^{-1})		
	N	P	K
Main plots: Fertility Levels (F)			
F_1:75 % RDF	150.0	39.5	139.4
F_2:100 % RDF	192.0	57.4	182.4
F_3:125 % RDF	201.3	71.0	200.5
SEm±	1.0	1.0	1.0
C D (P=0.05)	2.7	2.0	2
Sub plots: Weed Management (W)			
W_1- Atrazine 1000 g ha^{-1} as PE	180.8	54.6	175.1
W_2- Tembotrione 120 g ha^{-1} as PoE	183.3	56.9	173.9
W_3- Atrazine 750 g ha^{-1} as PE *fb* Tembotrione 90 g ha^{-1} as PoE	187.1	61.0	178.8
W_4- Atrazine 750 g ha^{-1} as PE *fb* Metsulfuron-methyl 4.0 g ha^{-1} as PoE	185.4	57.4	177.1
W_5- Straw mulch 5 ton ha^{-1} after emergence of crop	182.9	56.1	174.6
W_6- Live mulch with green gram up to 45 days then incorporation	182.3	54.3	173.4
W_7- Mechanical weeding (wheel hoe) at 20 and 40 DAS	183.8	56.3	177.1
W_8- Weedy check	163.2	51.0	162.8
SEm±	1.7	1.4	2.11
C D (P=0.05)	3.5	2.0	3.01
Interaction (FxW)	S	S	S
Interaction table			
F_1W_1	158.90	42.09	149.14
F_1W_2	160.51	43.09	150.62
F_1W_3	162.83	44.76	153.27
F_1W_4	153.96	41.73	144.52
F_1W_5	156.71	40.83	144.41
F_1W_6	162.20	41.53	148.16
F_1W_7	162.39	40.66	146.75
F_1W_8	134.44	38.34	138.81
F_2W_1	195.92	54.52	185.64
F_2W_2	204.99	62.52	194.86
F_2W_3	204.15	69.03	192.40
F_2W_4	203.53	61.68	196.83

F_2W_5	205.17	62.90	196.88
F_2W_6	208.65	59.07	195.13
F_2W_7	215.30	64.42	201.26
F_2W_8	178.90	55.12	180.78
F_3W_1	208.75	75.01	215.84
F_3W_2	204.77	74.59	204.95
F_3W_3	218.72	78.28	219.61
F_3W_4	215.49	77.28	216.61
F_3W_5	205.89	74.54	210.90
F_3W_6	202.72	71.16	205.20
F_3W_7	206.71	74.00	213.11
F_3W_8	197.45	70.90	206.58

Table 3: Economics of maize cultivation as influenced by fertility levels and weed management practices (pooled data of two years).

Treatments	Grain yield (q/ha)	Stover yield (q/ha)	Harvest index (%)	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio
Fertility Levels (F)						
F_1:75% RDF	48.4	86.2	32.9	94541	65327	2.24
F_2:100% RDF	62.5	109.1	35.4	112916	82586	2.72
F_3:125% RDF	71.2	126.5	39.3	135218	103849	3.31
SEm±	1.7	4.1	1.2	-	-	-
C D (P=0.05)	6.7	15.9	3.2	-	-	-
Weed Management (W)						
W_1	61.4	109.3	35.3	116120	86941	2.98
W_2	68.5	120.7	38.6	125790	95306	3.13
W_3	75.1	130.0	42.6	134510	103777	3.38
W_4	70.7	121.5	39.4	128550	98481	3.27
W_5	61.2	107.1	36.1	116190	84826	2.7
W_6	60.4	106.0	35.4	113000	80552	2.48
W_7	56.7	101.1	33.6	108090	77444	2.53
W_8	31.5	91.2	24.5	71550	43688	1.57
SEm±	1.5	2.4	0.7	-	-	-
C D (P=0.05)	4.4	6.7	2.0	-	-	-
Interaction (FxW)	S	NS	NS	-	-	-

Conclusion

It can be inferred that application 150:75:50 kg N: P_2O_5:K_2O ha^{-1} in the fertility levels of 125% RDF (F_3) is optimum for higher economic yield of maize. Through weed management practices yield can be enhanced to 58% as compared to weedy check. Higher yield, net returns and B:C ratio can be obtained with fertility levels F_3- 125% RDF (150:75:50 kg N:P_2O_5:K_2O_5) ha^{-1} along with W_3- Atrazine 750 g ha^{-1} as PE *fb* Tembotrione 90 g ha^{-1} as PoE at 2-4 leaf stage (F_3W_3).

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