

Brown manuring in maize (*Zea mays*): Effects on weed interference and crop productivity

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ABSTRACT

A field experiment was undertaken during rainy (*kharif*) season 2017 at ICAR-Indian Agricultural Research Institute, New Delhi to study the effects of brown manuring on weeds and maize (*Zea mays* L.) productivity. Season-long weed infestation (~unweeded control) resulted in the highest reduction (~41%) in grain yield of maize. Among the brown manuring (BM) treatments, growing of 1:1 mixture of *Sesbania bispinosa* (12.5 kg seed/ha) + *Crotalaria juncea* L. (12.5 kg seed/ha) supplemented with 2,4-D 0.5 kg/ha applied at 35 DAS, resulted in the highest reduction in weed density (~93%) and dry matter (~94.4%). This BM, in these regards, was comparable with the atrazine + hand weeding (HW) at 35 days after sowing (DAS) and weed-free control treatments. All BM treatments suppressed noxious weed *Cyperus rotundus*, which was poorly or not controlled by the recommended tank-mixture of atrazine and pendimethalin. Weed-free control resulted in the highest values of maize plant dry-matter (~210.6 g/plant), cob weight (~155.9 g/cob), and grain yield (~6.0 t/ha). The atrazine + HW, *Sesbania* + *Crotalaria* (12.5 + 12.5 kg/ha) mixture applied with 2,4-D 0.5 kg/ha at 25 DAS, *Sesbania* 25 kg/ha with 2,4-D 0.5 kg/ha at 25 DAS, and pendimethalin 0.75 kg/ha + atrazine 0.75 kg/ha treatments were comparable with weed-free control on maize grain yield.

Key words : *Crotalaria juncea*, Grain yield, *Sesbania bispinosa*, Weed interference

Maize is grown in an area of 9.5 million ha with annual production of 24.5 million tonnes and ranks third after rice and wheat in India (USDA, 2017). It is a miracle cereal crop, which serves humanity through various means, viz. food, feed, and fodder and basic raw materials for several industrial products (Dass *et al.*, 2008). The most dominant rice–wheat cropping system of India has encountered numerous problems, viz. nutrients imbalances, low input-use efficiency, more groundwater depletion and irrigation water scarcity, high energy and labour demands, high emissions of greenhouse gases, and weed shift and resistance (Humphreys *et al.*, 2010). Maize can replace rice in rice–wheat cropping system (Ladha *et al.*, 2009). But, weeds pose a never-ending challenge in maize production. Weed management using only herbicides may lead to non-target toxicity (Das *et al.*, 2010) and development of her-

bicide resistance in weeds (Das *et al.*, 2012). Integrated weed management (IWM), which is less herbicide-driven and more climate-resilient is required for sustainable maize production under changing climate. Brown manuring (BM) is a practice of growing *Sesbania/Crotalaria* as co-culture with a crop for a short period of 25–30 days after sowing (DAS), and then, killing by the application of post-emergence herbicides selective to the crop of prime interest (Tanwar *et al.*, 2010). In addition to weed management, BM offers multiple benefits such as improving organic matter, C and N reserves, and soil physical and biological properties. Hence, it can be a viable alternative to green manuring under no-till conservation agriculture. It is practised in direct-seeded rice crop and offers huge potential for adoption in maize. There are reports (Pandey *et al.*, 2003; Chalka and Nepalia, 2005) that intercropping maize with legumes can reduce weed dry weight significantly. Oyeogbe *et al.* (2017) reported that weed management through BM increased maize grain yield up to 10% compared to unweeded control.

Therefore, to investigate the effects of brown manuring on weed interference and maize crop productivity, an experiment was undertaken at the Division of Agronomy,

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ICAR-Indian Agricultural Research Institute, New Delhi (28°352 N latitude, 77°122 E longitude; altitude 228.6 meters above mean sea level) during rainy season in 2017. There were 12 treatments, laid out in a randomized block design with 3 replications. Among the treatments (Table 1), there were 8 BM treatments, which included 2 brown manure species (*Sesbania bispinosa*; *Crotalaria juncea*) sown at 2 seed rates (15 and 25 kg/ha) as sole/mixture (1:1), and were knocked down at 2 stages (25 and 35 DAS) using 2,4-D at 0.5 kg/ha. Four controls, namely, unweeded control, weed-free control, tank mixture of pendimethalin 0.75 kg/ha + atrazine 0.75 kg/ha, and atrazine 0.75 kg/ha + 1 hand-weeding (HW) at 35 days after sowing (DAS) were also adopted with BM treatments. In all BM treatments, pre-emergence application of pendimethalin 1 kg/ha was done. The soil of the experimental field was a sandy loam with pH 7.9 and organic carbon 0.60%, and medium in available P (15.5 kg/ha) and K (251.0 kg/ha) and low in available N (210 kg/ha). The climate is semi-arid, sub-tropical with hot and dry summers and cold winters. Maize 'PMH 1' was sown at 70 cm × 30 cm spacing with a seed rate of 20 kg/ha on July 13, 2017. Observations on density, dry-weight and weed-control efficiency of weeds (Das, 2008), and plant height and dry-weight, cob-weight and grain and stover yields of maize were taken at harvest. Maize grain yield was recorded at 15% moisture content (Oyeogbe *et al.*, 2017). An area of 90 cm (along the rows; ~3 plants) × 70 cm (across the rows; ~1 row) was randomly selected from the

central rows in each plot for collection of weed species and plant samples. Weed species were collected and maize plant height and dry weight was taken from that area. Data on weed population and dry weight had greater coefficient of variation than 20%, hence, were transformed through square-root ($\sqrt{x+0.5}$) method (Das, 1999). Data on weeds and maize were analysed by the analysis of variance (ANOVA) technique for randomized complete block design using MSTAT C software (CIMMYT, Mexico City, Mexico). The significance was tested by the variance ratio (~F value) at P = 0.05. Standard error (SE) and least significant difference (LSD) were calculated for comparing treatment means of the studied variables of weeds and crop.

All weed control treatments including brown manuring (BM) resulted in significant reduction in densities and dry weights of broad-leaved and grassy weeds, and total weeds (broad-leaved + *Cyperus rotundus* + grassy weeds) compared to unweeded control (Table 1). With respect to grassy weed, atrazine + HW resulted in 95% reduction in grassy weed density (4.67/m²), followed by *Sesbania* + *Crotalaria* (12.5 + 12.5 kg/ha) mixture applied with 2,4-D 0.5 kg/ha at 35 DAS, and tank-mixture of atrazine + pendimethalin. Vigorously growing maize crop canopy after removal of all weeds through HW at 35 DAS suppressed grassy weeds considerably, which might be the reason for the highest reduction of grassy weeds in atrazine + HW treatment. The density of *Cyperus rotundus* was the lowest due to the BM treatments such as *Sesbania*

Table 1. Effect of brown manuring on category-wise and total weed density (nos./m²), total weed dry-weight (g/m²) and weed control efficiency (WCE) at harvest of maize

Treatment	Weed density (no./m ²)*				Total weed dry weight (g/m ²)*	WCE (%)
	Broad-leaved	Grassy	<i>Cyperus rotundus</i>	Total		
<i>Sesbania</i> 15 kg/ha 2,4-D at 25 DAS	4.7 (22.3) †	5.3 (27.7) †	5.2 (27.0) †	8.8 (77.0) †	5.8 (33.8) †	73.8
<i>Sesbania</i> 25 kg/ha 2,4-D at 25 DAS	2.8 (8.3)	3.4 (11.3)	3.0 (9.3)	5.4 (29.0)	3.6 (12.8)	90.0
<i>Crotalaria</i> 15 kg/ha 2,4-D at 25 DAS	5.2 (27.0)	6.3 (40.7)	6.1 (37.0)	10.2 (104.7)	6.7 (44.4)	66.0
<i>Crotalaria</i> 25 kg/ha 2,4-D at 25 DAS	5.0 (23.0)	6.1 (31.7)	5.8 (31.0)	9.8 (85.7)	6.1 (36.7)	71.6
<i>Crotalaria</i> 15 kg/ha 2,4-D at 35 DAS	4.8 (26.0)	5.6 (36.3)	5.6 (33.7)	9.2 (96.0)	6.4 (41.2)	68.3
<i>Crotalaria</i> 25 kg/ha 2,4-D at 35 DAS	3.8 (14.0)	4.2 (17.3)	5.0 (24.3)	7.5 (55.7)	4.9 (23.3)	81.7
<i>Sesbania</i> + <i>Crotalaria</i> mixture (12.5 + 12.5 kg/ha) 2,4-D at 25 DAS	2.8 (7.7)	3.5 (14.0)	3.8 (14.0)	6.0 (35.7)	3.8 (14.5)	88.4
<i>Sesbania</i> + <i>Crotalaria</i> mixture (12.5 + 12.5 kg/ha) 2,4-D at 35 DAS	2.4 (5.7)	2.8 (7.7)	2.5 (6.3)	4.4 (19.7)	2.9 (8.6)	93.0
Atrazine + pendimethalin	3.8 (14.0)	3.0 (9.0)	7.2 (52.3)	8.7 (75.3)	5.3 (27.9)	75.3
Atrazine + HW	2.1 (4.0)	2.2 (4.7)	3.3 (11.3)	4.4 (20.0)	2.8 (7.6)	93.0
Unweeded control	11.8 (139.7)	9.9 (96.7)	8.2 (67.0)	17.4 (303.3)	12.6 (159.3)	0.0
Weed-free control	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	100.0
SEm±	0.5 (4.6)	0.5 (4.7)	0.5 (5.6)	0.6 (11.0)	0.4 (5.1)	2.7
CD (P=0.05)	1.5 (13.4)	1.5 (13.8)	1.5 (16.3)	1.8 (32.3)	1.3 (15.1)	8.1

*Data were subjected to $(x+0.5)^{1/2}$ transformation; †Figures in parentheses are original values

+ *Crotalaria* (12.5 + 12.5 kg/ha) mixture applied with 2,4-D 0.5 kg/ha at 35 DAS, and *Sesbania* 25 kg/ha applied with 2,4-D 0.5 kg/ha at 25 DAS; atrazine + HW; and *Sesbania* + *Crotalaria* (12.5 + 12.5 kg/ha) mixture applied with 2,4-D at 25 DAS were comparable. The tank-mixture of atrazine + pendimethalin, however, could not suppress *Cyperus rotundus*, which existed with 69.4% density of the total weed, which was obvious owing to the chemical nature of these 2 herbicides (both herbicides are not effective against *Cyperus rotundus*). The BM treatments were effective in controlling this sedge and resulted in significantly lower density compared to unweeded control, which might be due to biotic interference from brown manure species and/or allelopathic effect. Kaur *et al.* (2015) reported that intercropping may lead to weed suppression due to allelopathy. With respect to broad-leaved weed control, atrazine + HW resulted in about 97% control of broad-leaved weeds (4.0/m²), followed by *Sesbania* + *Crotalaria* (12.5 + 12.5 kg/ha) mixture with 2,4-D 0.5 kg/ha at 35 DAS, *Sesbania* + *Crotalaria* (12.5 + 12.5 kg/ha) mixture with 2,4-D 0.5 kg/ha at 25 DAS and *Sesbania* 25 kg/ha with 2,4-D 0.5 kg/ha at 25 DAS, which were on par. Weed-free control and atrazine + HW resulted in the lowest total weed density and dry weight, followed by *Sesbania* + *Crotalaria* (12.5 + 12.5 kg/ha) mixture + 2,4-D 0.5 kg/ha at 35 DAS. Among BM treatments, *Sesbania* + *Crotalaria* (12.5 + 12.5 kg/ha) mixture + 2,4-D applied at 35 DAS resulted in the lowest total weed density (~19.7/m²) and dry weight (~8.63g/m²) and the highest weed-control efficiency (~93%), but the atrazine + HW and weed-free control were on comparable with it. The positive effect of BM on weed control might be due to

early space capture, higher biomass, and larger canopy cover of brown manure species, leading to better suppression of weeds. Susha *et al.* (2018) reported similar weed suppression due to brown manuring in maize.

At harvest, weed-free control resulted in the highest maize plant height, dry-matter and cob weight (Table 2), followed by atrazine + HW, *Sesbania* + *Crotalaria* (12.5 + 12.5 kg/ha) mixture applied with 2,4-D 0.5 kg/ha at 25 DAS, *Sesbania* 25 kg/ha applied with 2,4-D 0.5 kg/ha at 25 DAS and tank-mixture of atrazine + pendimethalin, which were comparable with each other. Weed-free control gave significantly higher grain yield (~6.0 t/ha) and stover yield (8.7 t/ha), but atrazine + HW, *Sesbania* + *Crotalaria* (12.5 + 12.5 kg/ha) mixture applied with 2,4-D 0.5 kg/ha at 25 DAS, *Sesbania* 25 kg/ha with 2,4-D 0.5 kg/ha at 25 DAS and tank-mixture of atrazine + pendimethalin were comparable with it in these regards. The increases in grain yield in these treatments were 69.4%, 65.4%, 63.2%, 61.2% and 47.3% over that in unweeded control, respectively. This could be attributed to a better accumulation of plant biomass (source), which was later mobilized to the reproductive parts (sink) owing to lower crop-weed interference, which shifted the balance in favour of crop.

This study could reveal that BM, although may pose initial interference to maize during first 25 DAS, can be an effective weed management practice without any significant yield loss. A combination of 1:1 mixture of *Sesbania bispinosa* and *Crotalaria juncea* (12.5 + 12.5 kg/ha) and 2,4-D 0.5 kg/ha at 25 DAS would be the best possible BM practice in maize for higher productivity with acceptable higher weed-control efficiency.

Table 2. Effect of brown manuring on growth, yield attributes and yields of maize

Treatment	Plant height (cm)	Plant dry weight (g/plant)	Cob-weight (g/cob)	Grain yield (t/ha)	Stover yield (t/ha)
<i>Sesbania</i> 15 kg/ha 2,4-D at 25 DAS	196.3	180.2	136.0	4.8	8.0
<i>Sesbania</i> 25 kg/ha 2,4-D at 25 DAS	198.0	196.3	147.5	5.7	8.6
<i>Crotalaria</i> 15 kg/ha 2,4-D at 25 DAS	190.3	176.1	124.9	4.6	7.8
<i>Crotalaria</i> 25 kg/ha 2,4-D at 25 DAS	193.0	179.8	134.3	4.8	7.9
<i>Crotalaria</i> 15 kg/ha 2,4-D at 35 DAS	192.3	177.4	133.5	4.7	8.0
<i>Crotalaria</i> 25 kg/ha 2,4-D at 35 DAS	195.0	185.8	139.2	5.1	8.1
<i>Sesbania</i> + <i>Crotalaria</i> mixture (12.5 + 12.5 kg/ha) 2,4-D at 25 DAS	197.7	200.0	151.8	5.8	8.6
<i>Sesbania</i> + <i>Crotalaria</i> mixture (12.5 + 12.5 kg/ha) 2,4-D at 35 DAS	197.3	181.7	136.2	5.1	8.2
Atrazine + pendimethalin	196.7	194.7	142.7	5.2	8.4
Atrazine + HW	200.0	209.2	152.5	5.8	8.6
Unweeded control	187.3	148.4	122.6	3.5	6.2
Weed-free control	202.3	210.6	155.9	6.0	8.7
SEM±	2.8	7.7	5.1	0.3	0.4
CD (P=0.05)	8.1	22.5	15.1	0.8	1.1

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