Indian Journal of Weed Science (2023) **55**(3): 269–275
http://dx.doi.org/10.5958/0974-8164.2023.00050.3

RESEARCH ARTICLE

Integrated weed management in fodder maize crop in North-West India

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Received: 21 March 2023 | Revised: 17 July 2023 | Accepted: 20 July 2023

ABSTRACT

Field experiments were conducted in Punjab, India in 2020 and 2021 to study the integrated effects of row spacing, cultivars (variety) and weed control treatments on weed suppression and maize green fodder yield. The variety '*J-1007*' had higher maize equivalent fodder yield than the variety '*J-1006*' based on the averaged weed control treatments. Irrespective of the row spacing, the application of PoE herbicide tembotrione provided the highest maize equivalent fodder yield among all the weed control treatments and this treatment produced maize equivalent fodder yield of 43.28 and 47.97 t/ha for *J-1006* and *J-1007*, respectively in narrow 22.5 cm row spacing. Maize + cowpea intercropping provided similar level of weed control and yield as atrazine irrespective of the row spacing. The variety '*J-1007*' in 22.5 cm row spacing coupled with tembotrione accrued significantly lowest weed dry matter as compared to other treatment combinations. The study concluded that green fodder yield of maize cultivars could be improved by exploring their competitiveness through narrow row spacing and application of post-emergence herbicide tembotrione for weed control in maize fodder.

Keywords: Atrazine, Cultivar, Green fodder yield, Maize, Row spacing, Tembotrione, Weed control

INTRODUCTION

Maize (*Zea mays* L.) is one of the world's major cereal crops and is ranked third most important cereal crop after wheat and rice. During 2018-19 in India, maize area reached to 9.2 million hectare (DACNET 2020). A highly productive crop with diversified uses, maize is chiefly grown for human consumption in India, being a staple food of a large population (Milind and Isha 2013). Hence, it occupies a prominent place in the national food basket of the country. Besides its use in human diet, maize crop is extensively used as livestock feed for cattle, poultry and piggery in the form of green fodder and seed (Shah *et al*., 2016). Its use as green fodder has acquired immense importance because the quality of green fodder of maize is far excellent than other non-legume fodder crops (Kumar *et al*. 2017). It is the only non-legume fodder crop which produces better nutritional quality along with good quantity of biomass. It is commonly grown as a summer and rainy season fodder in the North-Western regions of the country, particularly in Punjab, Haryana and Western Uttar Pradesh. Its quality is much better than sorghum and pearl millet since both sorghum as well as pearl millet possesses anti-quality components such as hydrocyanic acid and oxalate (Hanif and Akhtar 2020).

Weed infestation in maize crop grown either for grain or fodder is one of the major causes behind heavy yield penalties. Particularly, in the early crop growing period, weed interference is a serious problem owing to its slow early crop growth rate. Also, coinciding rains especially during the rainy season help the weeds to grow faster and more luxuriantly. Weeds are notorious for competing successfully for resources mainly light, water and nutrients with the maize plants thus altering the maize crop morphology and phenology and ultimately reducing yield. Moreover, presence of weeds renders harvesting operations difficult and also mar the quality of the produce whether grain or green fodder (Ikram *et al*. 2018). The yield losses due to weeds generally depend on the composition of weed flora, duration of crop-weed competition and its intensity. Yield reductions of maize crop due to competition from weeds have been estimated to be around 37% (Oreke and Dehne 2004).

Currently, fodder producers are using pre-emergence (PE) herbicides chiefly atrazine for weed control in maize fodder which provides control of selected weed flora for first 3-4 weeks only. There is at present no post-emergence herbicide for weed control in fodder crop of maize. Now, atrazine, being a pre-emergence herbicide gives only selective weed

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control (Kumar *et al*. 2012) and weeds emerging in later flushes or which escape this herbicide continue to inflict heavy yield losses. Also, farmers sometimes skip the pre-emergent herbicide application and then they are left with no alternative in the absence of any recommendation for post-emergence herbicide application. Hence, it is pertinent to study the efficacy of post-emergence (PoE) herbicides in fodder maize. Recently introduced, a post-emergence herbicide labelled for use in grain crop of maize is tembotrione (Kaur *et al*. 2018). However, literature citing its use in fodder crop of maize is not available.

Although, the application of herbicides is inevitable and highly effective but the far-reaching consequence of heavy reliance on use of herbicides is mainly weed resistance (Mathers and Parker 2013). Crop competition can be employed as a potential valuable cultural weed control strategy in integrated weed management programme (Mohammadi *et al*. 2012) which would further contribute towards improving herbicide performance (Lodo *et al*. 2019). In maize, use of crop competition involves modification of row spacing, higher plant density, use of intercropping, use of competitive cultivars *etc*. (Ramesh *et al*. 2017, Mhlanga *et al*. 2016). These non-chemical weed control options can be used in conjunction with herbicides and weed control efficacy can be greatly enhanced. The present study aimed to find out the suitable row spacing to exploit the weed competitive ability of maize fodder cultivars along with suitable weed control treatments to reduce yield losses and weed infestation in maize fodder.

MATERIALS AND METHODS

The field experiments were conducted at the Fodder Research farm, Punjab Agricultural University, Ludhiana (30º54´N75º48´E), India, during the rainy seasons (June to October) of the year 2020 and 2021. The field had history of maize-oats (*Avena sativa*) rotation for fodder for the last 3 years. The climate at the site is semi-arid, with an average annual rainfall of 400 to 700 mm (75 to 80% of which falls from July to September), a minimum temperature of 0 to 4 ºC in January and a maximum temperature of 41 to 45 ºC in June. The soil at the experimental site was sandy loam with 0.3% organic matter and a pH of 7.2. During both years, same lands were prepared by ploughing twice using a cultivator followed by planking to make the soil well pulverized. Fodder maize was sown using 75 kg/ha seed rate at the seeding depth of 4-5 cm on 26 May, 2020 and 10 June, 2021 using a manual hand drill. The experiments were surface irrigated as and when required and depth of each irrigation was 5 cm. Nitrogen (120 kg/ha) as urea was applied (top-dressed) in two equivalent splits [(basal at sowing and 30 days after sowing (DAS)]. Recommended rates of chlorantraniliprole (9.25 g/ha) were used to control pests. The crop was harvested at 75-80 DAS on August 20 and August 30 during 2020 and 2021, respectively.

The experiment in each year was established in a factorial split-plot design with three replicates. The study included 16 treatments consisting of two row spacings (wide: 30-cm row spacing and narrow: 22.5-cm row spacing) and two cultivars (J-1006 and J-1007) in main plots and four weed control treatments (non-treated control, atrazine 625 g/ha, tembotrione 120 g/ha and maize + cowpea intercropping) in subplots. Atrazine (3 DAS) and tembotrione (20-25 DAS) were applied using a knapsack sprayer with a flood jet and flat-fan nozzle, respectively. For PE and PoE application of herbicides, the sprayer was calibrated to deliver 500 and 375 litres of spray solution per hectare, respectively. In maize + cowpea intercropping, one row of cowpea was sown between two maize rows using a seed rate of 15 kg/ha. The sowing of cowpea was done simultaneously with maize sowing. Two quadrats, 0.25 m^2, were placed at random in each plot to determine weed density and dry weight at 45 DAS and at harvest. For dry weight, weeds were cut close to the ground level, air-dried and then dried in an oven for 72 hours at 60ºC, and dry weight was recorded.

Five plants were selected randomly from each plot to measure plant height at regular intervals (30 DAS, 45 DAS and at harvest). Leaf area index of maize was recorded at regular intervals (30 DAS, 45 DAS and at harvest) using prescribed procedure (Sexsana and Singh, 1968).

The crop was harvested for taking green fodder yield at dough stage (75-80 DAS). The green fodder yield from each plot was immediately weighed in kg/plot and then expressed in t/ha. Both maize and intercrops were harvested separately from intercropping plots by using sickle. The green fodder yield of intercrop was converted into maize fodder equivalent yield by multiplying the prevailing market price of intercrop with its yield and then dividing price of sole maize fodder and expressed in t/ha.

Maize fodder equivalent yield (MEY) was calculated as:

$$\text{Maize fodder equivalent yield} = \frac{\text{Yield of cowpea} \times \text{price of cowpea/kg}}{\text{Price of maize/kg}}$$

Since the interaction of years with treatments were insignificant, the data were pooled for the two years for further analyses using the GLM procedure in SAS version 9.3 to evaluate the differences between treatments (SAS 9.3). Using square-root transformation, data on weed dry matter were transformed. Treatment means were separated using Fischer's protected least significant difference (LSD) at the 5% level of significance.

RESULTS AND DISCUSSION

Weeds density

The experimental field was dominated by *Digitaria sanguinalis*, *Dactyloctenium aegyptium*, *Echinochloa colona* under grasses; *Trianthema portulacastrum*, *Euphorbia hirta*, *Eclipta alba* under broadleaved weeds (BLWs); *Cyperus rotundus* under sedges. The different treatments significantly influenced the density of grasses, braod-leaved weeds (BLWs) and sedges at 45 DAS and at harvest (**Table 1**). Fodder maize cultivars had significant influence on density of weeds. Significantly higher density of grasses and BLWs were recorded in cultivar *J-1006* which could be due to shorter plant height and less leafiness of *J-1006* as compared to *J-1007*, which recorded lower weed density due to its more plant height and canopy coverage while the density of sedges was not affected by the cultivars. Between the two row spacings, significantly maximum density of grasses, BLWs and sedges was observed in wide 30 cm row spacing at both the stages. Among the weed control treatments, significantly lowest density of weeds was found in plots treated with PoE application of tembotrione. Maize + cowpea intercropping remained more or less similar in reducing density of weeds as PE application of atrazine. The interaction of the treatments was, however, non-significant with respect to weed density.

There was significant interaction among treatments with regard to weed dry weight at 45 DAS and at harvest (**Table 2** and **3**). As compared to weed density, weed dry matter is a better measure of weed growth because it combines weed density as well as size. At 45 DAS, total weed dry matter varied from 39.8 to 340.6 g/m^2 in different combinations of row spacing, cultivars and weed control treatments. The lowest weed dry matter was recorded in cultivar *J-1007* sown with narrow 22.5-cm row spacing coupled with PoE application of tembotrione. The highest total weed dry matter was found in the non-treated plots sown with cultivar *J-1006* with wide 30-cm row spacing. A similar response was observed at the harvest stage where total weed dry matter varied from 22.4 to 222.7 g/m^2 in different treatment combinations of row spacing, cultivars and weed control treatments. At 45 DAS, cultivar *J-1007* sown with narrow 22.5-cm row spacing and sprayed with PE application of atrazine produced total weed dry matter similar to that with either cultivar sown with wide 30-cm row spacing and sprayed with PoE application of tembotrione. These combinations were also at par with cultivar *J-1006* sown with narrow 22.5-cm row spacing and treated with PoE herbicide. Cultivar *J-1007* sown with narrow 22.5-cm row spacing and in intercropping with cowpea reduced total weed dry matter similar to when this cultivar was sown with wide 30-cm row spacing and sprayed with PoE application of tembotrione and when sown in 22.5 cm rows and treated with PE atrazine. These combinations were also at par with cultivar *J-1006* sown in wide 30 cm rows and sprayed with PoE herbicide or cultivar *J-1006* sown in 22.5 cm rows and sprayed with PE herbicide.

The cultivar *J-1006* sown in 22.5 cm rows exhibited more reduction in dry matter of total weeds

Table 1. Weed density in relation to different treatments at 45 DAS and at harvest (pooled data of two years)

Treatment	Weed density (no./m^2)					
	45 DAS			At harvest		
	Grasses	BLWs	Sedges	Grasses	BLWs	Sedges
Cultivar						
J-1006	7.1 (53.7)	6.5 (45.1)	7.0 (50.2)	6.2 (40.3)	5.6 (32.3)	6.2 (39.4)
J-1007	6.5 (46.3)	6.4 (42.6)	6.8 (47.7)	5.7 (34.2)	5.3 (29.4)	5.9 (36.1)
LSD (p=0.05)	0.2	NS	NS	0.4	0.2	
Row spacing (cm)						
30	7.6 (61.0)	6.9 (50.1)	7.3 (55.1)	6.5 (43.7)	5.6 (32.5)	6.7 (45.3)
22.5	6.0 (39.0)	6.0 (37.6)	6.5 (42.8)	5.4 (30.9)	5.3 (29.2)	5.4 (30.2)
LSD (p=0.05)	0.2	0.2	0.3	0.4	0.2	0.4
Weed control treatment						
Weedy check	9.8 (96.7)	9.1 (82.8)	9.0 (81.5)	8.1 (66.0)	7.4 (54.8)	7.8 (60.7)
Atrazine 625 g/ha	6.3 (39.6)	6.0 (35.9)	6.4 (40.0)	5.7 (31.5)	5.3 (26.9)	5.8 (33.2)
Tembotrione 120 g/ha	4.2 (17.4)	4.4 (18.6)	5.5 (29.2)	3.9 (15.2)	3.6 (11.9)	4.5 (19.8)
Maize + Cowpea intercropping	6.8 (46.3)	6.3 (38.2)	6.8 (45.0)	6.1 (36.5)	5.5 (29.7)	6.1 (37.4)
LSD (p=0.05)	0.7	0.4	0.4	0.4	0.3	0.3

Table 2. Total weed dry weight in relation to the integrated effect of treatments at 45 DAS in maize fodder (pooled data of 2 years)

Treatment	Total weed dry weight (g/m^2)			
	30 cm row spacing		22.5 cm row spacing	
	J-1006	*J-1007*	*J-1006*	*J-1007*
Nontreated control	18.5 (340.6)	18.2 (329.0)	17.6 (307.9)	17.1 (289.8)
Atrazine	10.4 (106.5)	9.9 (97.8)	9.0 (80.6)	8.1 (64.7)
Tembotrione	8.8 (75.7)	8.0 (63.2)	7.9 (62.2)	6.4 (39.8)
Maize + cowpea intercropping	10.3 (104.2)	10.1 (101.0)	9.5 (90.2)	8.8 (77.4)
LSD (p=0.05)	0.8			

*Weed dry weight data were subjected to square-root transformation before analysis and original values are presented in parentheses

Table 3. Total weed dry weight in relation to the integrated effect of treatments at harvest in maize fodder (pooled data of 2 years)

Treatment	Total weed dry weight (g/m^2)			
	30 cm row spacing		22.5 cm row spacing	
	J-1006	*J-1007*	*J-1006*	*J-1007*
Nontreated control	15.0 (222.7)	13.8 (190.0)	13.3 (176.9)	12.6 (157.4)
Atrazine	8.7 (75.1)	8.0 (63.5)	7.8 (59.2)	6.9 (46.7)
Tembotrione	7.7 (59.0)	7.4 (53.9)	7.0 (48.7)	4.8 (22.4)
Maize + cowpea intercropping	9.4 (87.9)	8.1 (65.0)	8.1 (65.6)	7.0 (48.6)
LSD (p=0.05)	0.5			

*Weed dry weight data were subjected to square-root transformation before analysis and original values are presented in parentheses

at both the stages when sprayed with PE herbicide as compared with PoE herbicide. Weed dry matter was lower in *J-1007* than *J-1006* in narrow 22.5 cm row spacing when treated with PE and PoE sprays. The PoE application of tembotrione resulted in the lowest total weed dry matter compared with other treatments at both stages. The cultivar *J-1006* in narrow 22.5 cm row spacing and in intercropping with cowpea resulted in total weed dry matter (at 45 DAS and at harvest) similar to that in wide 30-cm row spacing and sprayed with tembotrione. At 45 DAS, *J-1007* in 22.5 cm row spacing resulted in reduction in dry matter of total weeds from 329 to 289.8 g/m^2 compared with 30-cm row spacing in non-treated control plots. With PE spray of atrazine, dry matter of total weeds at 45 DAS in 22.5 cm row spacing decreased from 97.8 to 64.7 g/m^2 and 106.5 to 80.6 g/m^2 for *J-1006* and *J-1007*, respectively, compared with 30 cm row spacing. With PoE spray of tembotrione, dry matter of total weeds at 45 DAS at 22.5 cm row spacing decreased from 63.2 to 39.8 g/m^2 for *J-1007* compared with 30 cm row spacing, however, no such reduction was observed for *J-1006*. A similar response was observed at harvest stage. With PE application of atrazine, dry matter of total weeds at harvest in 22.5 cm row spacing reduced from 75.1 to 63.5 and from 59.2 to 46.7 g/m^2 for *J-1006* and *J-1007*, respectively compared with 30 cm row spacing. With PoE application of tembotrione, the dry matter of total weeds decreased from 48.7 to 22.4 g/m^2 for *J-1007* compared with 30 cm row spacing; however, no such reduction was noticed for *J-1006*. The correlation of weed dry matter at harvest with maize equivalent fodder yield was negative indicating that weeds accounted for 92% of the variation in green fodder yield (**Figure 1**). In maize crop, weeds seriously compete for different resources and cause significant reductions in yields (Bajwa *et al*., 2015).

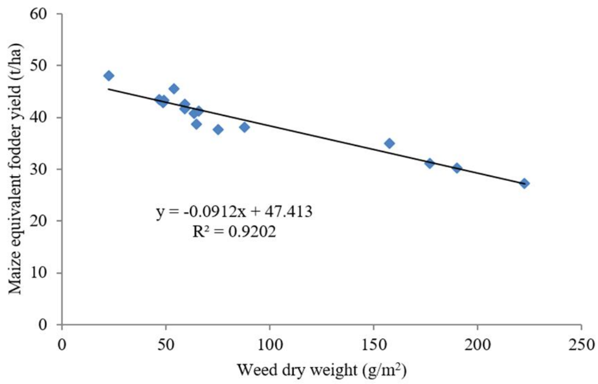

Figure 1. Relationship of weed dry weight and maize fodder equivalent yield at harvest

A practical management strategy to have a significant impact on weeds in crops is the manipulation of row spacing. The rate at which crop canopy closes *i.e.*, overlapping of leaves from the adjoining rows is highly determined by the row spacing which also affects the growth of weeds especially in the inter-row area. Significant yield losses occur when weeds out-compete the crops for essential nutrients. Reducing the row spacing of the crop reduces the time the crop takes to quickly cover the ground and close the canopy, hence providing rapid shading and suppressing weed growth and weeds' competitive abilities (Daramola *et al* 2021). Also, reduction in weed dry weight in narrower rows is attributed to increased LAI of the crop which restricts the solar radiation from reaching the weeds. Further, selecting a weed competitive cultivar confers suppression on weed infestation. A few studies have indicated that maize cultivars with greater leaf area index and more plant height have more suppressive effects on weeds (Lindquist and Mortensen 1998). In the present study, *J-1007* caused 9.0 and 18.5% reduction in weed dry weight at 45 DAS and at harvest, respectively over *J-1006*. The results of the present study thus corroborate the previous findings that changes in row spacing and selection of competitive cultivar influence weed growth. Among the herbicide options available for maize, atrazine has been the primary choice of farmers and it provides effective control of annual grasses and broadleaf weeds but for the complex weed flora and later emerging weeds, it is less effective. The new maize herbicide tembotrione is found to be very effective against a wide range of grass and broad-leaf weeds especially as post-emergence (Kaur *et al.* 2018). In the present study, the lowest weed dry matter was recorded with the application of PoE tembotrione in different combinations of row spacings and cultivars at both the stages. This could be due to the effective control of weeds emerging in the later flushes. Maize + cowpea intercropping caused reduction in weed dry weight which was comparable to the application of herbicide especially PE herbicide. Earlier also, it has been reported that maize + cowpea intercrops reduced weed dry weight as compared to sole crops due to the limited availability of resources to the weeds and also there was significant reduction in photo-synthetically active radiation reaching the ground by maize + cowpea intercrops (Eskandari and Kazemi 2011).

Plant height and leaf area index of the crop

There was no phyto-toxicity of either herbicide on maize fodder crop at the three observation stages (data not shown) which indicated that both PE and PoE herbicides are safe to the maize fodder crop. Plant height of the crop increased with successive stages up to harvest, however, the magnitude of the increase in plant height was found to get reduced beyond 45 DAS (**Table 4**). At each observation stage, plant height of the maize fodder was more at 22.5 cm row spacing. At harvest, the average plant height was 230.1 cm at 22.5 cm row spacing compared with 216.0 cm at 30-cm row spacing. At each observation stage, averaged over row spacings and weed control treatments, the plants of cultivar *J-1007* remained taller than the cultivar of *J-1006*. In weed control treatments, plants attained maximum height in the plots treated with the PoE application of tembotrione. The lowest plant height was recorded in the non-treated control plots at each stage.

Similar to plant height, leaf area index of the maize fodder was significantly affected by different treatments (**Table 5**). Leaf area index is a fair and reliable parameter of plant growth. It is an important indicator of radiation interception by each plant which affects plant growth and ultimately reflects in final dry matter yield. At 30 DAS, leaf area index of the crop in narrow 22.5 cm row spacing was 2.56 compared with 2.44 in wide 30 cm row spacing. At harvest, these values were 8.55 and 8.11 at 22.5 cm and 30 cm row spacing, respectively. The variety *J-1007* had higher leaf area index than *J-1006* at each stage. At harvest, the leaf area index of *J-1007* was 9.6% higher than that of *J-1006* plants. Among the weed control treatments, the leaf area index was highest with PoE application of tembotrione and lowest in non-treated control plots at each observation stage.

Table 4. Plant height of maize fodder in relation to different treatments at different stages of plant growth (pooled data of two years)

Treatment	Plant height (cm)		
	30 DAS	45 DAS	At harvest
Cultivar			
J-1006	56.5	131.6	218.5
J-1007	58.9	141.0	227.5
LSD (p=0.05)	NS	3.1	5.4
Row spacing (cm)			
30	56.7	131.4	216.0
22.5	58.8	141.1	230.1
LSD (p=0.05)	NS	3.1	5.4
Weed control treatment			
Weedy check	54.4	123.0	203.9
Atrazine 625 g ai/ha	58.7	141.3	229.2
Tembotrione 120 g ai/ha	60.0	147.8	240.9
Maize + cowpea intercropping	57.7	133.0	218.2
LSD (p=0.05)	2.8	4.1	6.1

Table 5. Leaf area index of maize fodder in relation to different treatments at different stages of plant growth (pooled data of two years)

Treatment	Leaf area index		
	30 DAS	45 DAS	At harvest
Cultivar			
J-1006	2.41	4.65	7.95
J-1007	2.62	5.18	8.71
LSD (p=0.05)	0.073	0.28	0.26
Row spacing (cm)			
30	2.44	4.73	8.11
22.5	2.56	5.09	8.55
LSD (p=0.05)	0.073	0.28	0.26
Weed control treatment			
Weedy check	2.00	4.23	7.26
Atrazine 625 g/ha	2.66	5.16	8.68
Tembotrione 120 g/ha	2.93	5.52	9.34
Maize + cowpea intercropping	2.47	4.75	8.04
LSD (p=0.05)	0.13	0.29	0.52

Plant height is an important component which determines the growth attained during the growing period and ultimately the green fodder yield in maize crop. In the present study, the maximum plant height was attained at narrow 22.5 cm row spacing. Increase in plant height due to closer row spacing might be attributed to better vegetative development resulting in increased mutual shading and inter-nodal extension. Also, as the number of plants increased, the competition among the plants for nutrients uptake and particularly sunlight interception increases which finally brings an increase in plant height.

Leaf area index is another important feature of maize fodder crop as the final green fodder yield is greatly determined by the leafiness of the crop per unit area. In our research, narrowing down the row spacing is observed to have an increase in LAI of the crop on account of more ground area covered by the green leafy canopy of plants per unit area. An increase in leaf area index helps capture more solar radiation and thus accumulation of more dry matter and ultimately more economic yield. The results of the present study are in close conformity with the results documented by Sharifi and Namvar (2016) who found that increase in plant density, increases the LAI in maize.

Among the important traits of cultivars conferring weed suppression, faster growth and development, improved plant height and presence of more light-intercepting leaf architecture are prominent. As compared to cereals such as wheat and rice, limited work pertaining to use of competitive cultivars has been done in maize. In a study by Lindquist and Mortensen (1998), the weed suppressive ability of maize cultivar was due to its greater leaf area index. Similarly, in our study, the cultivar *J-1007* had more competitive ability that *J-1006*. This response was accounted for by more plant height and leaf area index of *J-1007* which helped in early crop canopy closure and gave more smothering effect on weeds at both the stages of observation.

Maize fodder equivalent yield

Maize fodder equivalent yield was significantly influenced by row spacing, cultivars and weed control treatments (**Table 6**). Maize fodder equivalent yield varied from 27.25 to 47.97 t/ha in different combinations of row spacing, cultivars and weed control treatments. In the non-treated control plots, *J-1007* produced more green fodder yield over *J-1006* irrespective of row spacing and green fodder yield of *J-1007* further improved at 22.5 cm row spacing compared to 30 cm row spacing. In non-treated control plots, *J-1007* sown with 22.5 cm row spacing produced green fodder yield which was significantly highest as compared to other combinations of cultivars and row spacing with non-treated control. The green fodder yield of both the cultivars was similar in plots sprayed with PoE herbicide irrespective of row spacing. *J-1007* sown at 22.5 cm row spacing and sprayed with PE herbicide resulted in green fodder yield similar to that obtained with *J-1006* sown with either row spacing and sprayed with PoE herbicide. In intercropping with cowpea, row spacing had no influence on maize equivalent fodder yield between the cultivars. In either row spacing, maize + cowpea intercropping provided similar maize equivalent fodder yield in both cultivars. Additionally, maize + cowpea intercropping provided green fodder yield in both the cultivars similar to when sprayed with atrazine. With the application of atrazine, green fodder yield at 22.5 cm row spacing was 10.7 and 6.6% higher than in the 30-cm row spacing for *J-1006* and *J-1007*, respectively. With the application of tembotrione, green fodder yield increased by 5.5% at 22.5 cm row spacing for *J-1007* compared with 30 cm row spacing, however, no such increase was found for *J-1006*.

Table 6. Maize fodder equivalent yield in relation to interactive effect of row spacing, cultivars and weed control treatments (pooled data of two years)

Treatment	Maize fodder equivalent yield (t/ha)			
	30 cm row spacing		22.5 cm row spacing	
	J-1006	*J-1007*	*J-1006*	*J-1007*
Nontreated control	27.25	30.29	31.14	34.96
Atrazine	37.58	40.72	41.59	43.41
Tembotrione	42.63	45.49	43.28	47.97
Maize + cowpea intercropping	38.07	38.67	41.13	42.83
LSD (p=0.05)	2.56			

In conclusion, green fodder yield of maize could be enhanced by selecting the weed competitive cultivar in narrow rows coupled with PoE herbicide tembotrione or intercropping to achieve higher returns (**Table 7**). The total residue of herbicide tembotrione in maize grain and cob matrix were both below 0.02 mg/kg, lower than the max residue limit (MRL) recommended by European Food Safety Authority (EFSA), however, similar studies are required to determine the residues of tembotrione in maize green fodder.

Table 7. Economics of maize fodder in relation to different treatments at (pooled data of two years)

Treatment	Gross returns ($x10^3$ ₹/ha)	Net returns ($x10^3$ ₹/ha)	Benefit: cost ratio
Cultivar			
J-1006	93.96	56.15	2.48
J-1007	101.97	62.93	2.60
LSD (p=0.05)	4.37	4.37	0.11
Row spacing (cm)			
30	94.58	56.19	2.45
22.5	101.35	62.89	2.63
LSD (p=0.05)	4.37	4.37	0.11
Weed control treatment			
Weedy check	77.27	40.87	2.12
Atrazine 625 g/ha	102.06	64.34	2.70
Tembotrione 120 g/ha	112.10	71.53	2.76
Maize + cowpea intercropping	100.43	61.42	2.57
LSD (p=0.05)	2.81	2.81	0.07

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