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Organic Methods of Weed Control in Brinjal (*Solanum melongena* L.) Cultivation- Alternative to Conventional Chemical Control

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The current study, named "Development of organic farming package for brinjal (*Solanum melongena* L.)," was carried out at the Mahatma Phule Krishi Vidyapeeth's Research Farm in Rahuri, District of Ahmednagar, Maharashtra (India), during the kharif seasons of 2017 and 2018. Due to weed free treatment followed by mechanical (hoeing) intercultivation and pulling of weeds at 20 days intervals from 20 to 80 days after transplanting of brinjal 2017 and 2018, monocot and dicot weed intensity, category wise weed density (grasses, broad-leaved weeds, sedges), and total dry matter of weeds were significantly at lower magnitudes and weed control efficiency was at higher magnitudes. Weed index was also significantly lower. The mechanical (hoeing) intercultivation method followed by weed-free culture resulted in significantly higher parameters for growth for brinjal.

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1. INTRODUCTION

"Brinjal (*Solanum melongena* L.) is one of the most common tropical vegetable grown in India. It is a versatile vegetable crop grown as a poor man's crop, adapted to different agro-climatic regions and can be grown throughout the year. It is an important vegetable due to its nutritive value, consisting of minerals like iron, phosphorus, calcium and vitamins like A, B and C. Our demand by 2020 will be around 250 million tonnes of vegetables" [1]. "In India, brinjal occupies an area of 10 lakh ha with a production of 1.87 million tonnes with average productivity of 17.96 t ha^{-1}" [2]. "In Maharashtra, it is cultivated over an area of 68 thousand ha with a production of 11 lakh million tonnes with an average productivity of 17.00 t ha^{-1}" [2].

"Among the various factors responsible for the low productivity of brinjal, weed menace and nutrient status of soils are considered to be major ones. There is tremendous scope for increasing the yield of brinjal up to 60 t ha^{-1}. Weeds can be considered a significant problem because they tend to decrease crop growth and yields by increasing competition for soil moisture, sunlight, space and nutrients while serving as host plants for pests and diseases. On account of the early establishment and faster growth characteristic, weeds tend to have an upper hand on the crop. Among the various kinds of pests, the yield reduction in brinjal due to weed alone range from 49 to 90 per cent" [3].

Weeds are the major constraints in realizing optimum yield potential. They may cause a drastic reduction in yield to a level of one-third to almost total failure of the crop. It is well established that losses caused by weeds exceed the losses from any other category of agricultural pests like insects, diseases or rodents. Unlike insect-pest and disease outbreak, losses due to weeds do not show any clear visual symptom especially at the early stages of growth. The magnitude of the effect depends upon weed species, their intensity, duration of infestation, stages of the critical competition and other management factors.

Weed management in organic vegetable production system must involve the use of many techniques and strategies, all to achieve economically acceptable weed control and crop yields. Hence effective non-chemical weed management needs to give special attention concerning increasing the brinjal production under the organic scenario. Most organic crop growers rely on cultivation or tillage, hoeing and hand weeding as a safe and available method for controlling weeds, but these tools can add significantly to production costs. Besides, frequent tillage can reduce soil health and quality and cause additional weed flushes.

Soil coverage with organic mulches is one of the natural methods of preventing weed infestation. It can be achieved by using plant mulches and mulches from straw left after the cereal grain harvest. Despite the serious threat, weeds offer to organic crop production relatively little attention has so far be paid in research on weed management in organic in general and brinjal in particular.

"There are several alternatives for the supply of soil nutrients from organic sources like farmyard manure, green manure, compost, vermicompost, organic cakes and biofertilizers etc., which also supplement the secondary micronutrients to crops. Soil fertility management is an important and costly cultural practice for organic vegetable growers. Complete organic production warrants the use of organic sources in plant nutrition, plant protection and all other related crop production practices. Cultivation of any crop depends on several factors and sources of nutrients are one of them. Organic sources of nutrients are less expensive and friendly to the environment. To minimize the economic return avoiding health hazards and for sustainable agriculture, the use of organic sources of nutrients should be encouraged. FYM, Vermicompost and Neem seed cake are commonly used sources of N for vegetables because they are relatively inexpensive and offer additional nutrients for soil improvement in addition to N. The use of biofertilizers in such a situation is, therefore, a practically paying proposal. P solubilizers are biofertilizers that solubilize phosphorus in soil and make it available to plants while *Azospirillum*, a heterotrophic nitrogen-fixing organism has been reported to be beneficial and economical on several crops. They improve growth and yield as well as the productivity of crops". [4]

2. MATERIALS AND METHODS

Field experiment entitled "Development of organic farming package for brinjal (*Solanum* *melongena* L.)" was conducted at Mahatma Phule Krishi Vidyapeeth, Rahuri, during two successive years *viz*., 2017 and 2018, respectively.

"The experimental soil was clay loam in texture, alkaline in reaction (pH 8.17) with electrical conductivity 0. 29 dSm^{-1}. The soil was low in organic carbon (0.52 %) and available nitrogen (181.33 kg ha^{-1}), medium in available phosphorus (15.79 kg ha^{-1}) and very high in available potassium (403.56 kg ha^{-1}), respectively. The bulk density, infiltration rate, field capacity, permanent wilting point and porosity of the soil were 1.33 g m^{-3}, 8.71 cm hr^{-1}, 36.30, 18.32 and 47.33 per cent, respectively. Thus soil was suitable for growing of brinjal in *kharif* season". [4]

The experiment was laid out in strip plot design with three replications. The main plot treatments were applied to brinjal comprised of non-chemical weed control modules *viz.* W_1 **-** *Gliricidia* leaf mulching @ 5 t ha^{-1}, W_2 -Biodegradable mulch (soybean straw) @ 5 t ha^{-1}, W_3-Mechanical (hoeing) intercultivation and pulling of weeds, W_4-Control -Weedy check, W_5- Weed free (Hand weedings with 15 days interval). Different organic nutrients sources and biofertilizers *i.e. Azospirillum* and *PSB* as a (1 :1) @ 500 g 10 lit^{-1}) as sub plot treatments which comprised of seven organic sources treatments *viz.*, O_1**-** 100 % RDN through FYM with biofertilizers, O_2-100 % RDN through vermicompost with biofertilizers, O_3-100 % RDN through neem cake with biofertilizers, O_4-50 % RDN each through FYM and vermicompost with biofertilizers, O_5-50 % RDN each through FYM and neem cake with biofertilizers, O_6- 50 % RDN each through vermicompost and neem cake with biofertilizers, O_7- 1/3 N each through FYM, vermicompost and neem cake with biofertilizers.

The climatic condition was favorable for crop during both the years. The total rainfall received during crop growth period was 486.9 mm and 139.2 mm in 20 and 09 rainy days and it was 8.23 and 73.59 per cent less during first and second year as compared to average annual rainfall (527 mm). But maximum and minimum temperature as well as morning and evening relative humidity was in optimum range which create congenial condition for optimum growth of crop". [4]

Brinjal Cv. Manjarigota was used as a test crop which is suitable for irrigated condition. It was procured from the Vegetable Scheme, M.P.K.V., Rahuri. It is indeterminate and open pollinated variety. Generally organic farming, the open pollinated or deshi type variety is used as a test crop because it's not contains any hybridizing material. As per the treatments mulch of *gliricidia* leaf on wet weight basis @ 5 t ha^{-1} and soybean straw on dry weight basis @ 5 t ha^{-1} applied two days after transplanting of the brinjal crop. As per the treatments mechanical (hoeing) intercultivation carried out by machine operated hand hoe at 20, 40, 60, 80 DAT. As per the treatment hand weeding in weed free plot was carried out by weeding hook i.e. five hand weeding at 15 days intervals to keep plots weed free up to 80 days. Weed counts and weed sample for dry matter were taken at 30, 60, 90 and 120 DAT to assess the effect of various treatment of weed growth. An area of 1.0 m^{-2} was selected randomly by throwing a quadrant. Species wise weed density count was made from the quadrant data. The plant height, number of primary branches plant^{-1}, number of secondary branches plant^{-1}, total number of branches plant^{-1}, number of leaves plant^{-1}, leaf area plant^{-1}, dry matter plant^{-1}, of brinjal was measured at 30, 60, 90 and 120 DAT from the randomly selected observational plants from each treatments. Weed density and dry weight were square root transformed, before analysis. However, for better understanding, original values are given in parenthesis. The experimental data was subjected to analysis adapting data obtained on various variables were analyzed by 'Analysis of Variance' method [5]. Data analyzed by using strip plot design. Wherever, the results were found to be significant, critical difference was calculated at P=0.05 by the formula.

$$C.D. = S.E.m\pm \times 2 \times t \text{ at error d.f.}$$

The pooled analysis was carried out as per the procedure outlined by Cochran and Cox [6]. The homogeneity of error variance was tested by applying the Bartlett's test.

3. RESULTS AND DISCUSSION

3.1 Weed Flora

The major weed flora observed in the experimental field of brinjal during 2017 and 2018 were *Cynodon dactylon* L., *Digitaria sanguinalis* L. Scop., *Dinebra retroflexa* (Vahl.) Panz, *Brachiaria erusiformis* (Sm.) and *Cyperus rotundus* L. among the monocot weeds, while among the dicots weeds *Amaranthus polygymus* L., *Amaranthus viridis* Hook. F., *Parthenium* *hysteriphorus* L., *Convolvulus arvensis* L. and *Euphorbia hirta* L. The broad-leaved weed dominated at all stages of brinjal crop growth, followed by grasses and sedges In the experimental field broad leaved weeds had major share of weed density, throughout the period of investigation and constituted 49.48 and 49.28 per cent, grasses 35.80 and 35.35 per cent, sedges 15.25 and 15.37 per cent during 2017 and 2018, respectively. Among the broad-leaved weeds *Parthenium hysteriphorus* (16.04 and 15.84 %), among the grasses, *Cynodon dactylon* (11.95 and 11.84 %) and *Cyperus rotundus* in sedges (15.25 and 15.37 %) contributed major density of weeds during the years 2017 and 2018, respectively.

3.2 Weed Dynamics

3.2.1 Effect of non-chemical weed control modules on weed composition and category wise weed density (No.m^{-2})

In experimental field monocot and dicot weeds had major share of density of weed throughout the growth period. At 120 days after transplanting of brinjal the major weed flora comprised of monocot weeds *viz. Cynodon dactylon, Dagitaria sanguinalis, Dinebra retroflexa, Brachiara erusiformis* and *Cyperus rotundus* and dicot weeds *viz. Amaranthus polygymus, Amranthus viridis, Parthenium hysteriphorus, Convolvulus arvensis, Euphorbia hirta* in 2017 and 2018 are presented in Table 1. The highest weed infestations of monocot and dicot weeds and total weeds were recorded in weedy check plot followed by mulch- soybean straw @ 5 t ha^{-1} at 120 days after transplanting during both the years of experimentation. Adoption of hoeing and pulling of weeds caused reduction in weed number of monocot weeds, dicot weeds and total number of weeds over rest of weed control treatments. While comparing other non-chemical weed control modules with minimum population recorded in weed free treatment. This might be observed due to weed free condition and mechanical weeding created less weed density and weed crop competition for moisture, nutrients, space and CO_2. Similar results observed by Mansuri [7], Thakur et al. (2013) and Das et al. [8]. Effect of non-chemical weed control modules on the density of grassy weeds, broad-leaved weeds, sedges and total weed density (No.m^{-2}) was found significant at all the growth stages of observations during 2017 and 2018. All non-chemical weed control modules led to significant reduction in density of grassy weeds, broad-leaved weeds, sedges and total weed at all the stages of observation compared to weedy check. The significantly lowest grassy weeds, broad-leaved weeds, sedges and total weed density (No.m^{-2}) was recorded under the weed free check treatment than rest of the weed control treatments. However, it was at par with hoeing and pulling of weeds of brinjal followed by weed control treatment of *gliricidia* leaf mulching @ 5 t ha^{-1}, mulch- soybean straw @ 5 t ha^{-1} during both the years. The weedy check recorded significantly higher weed density (No. m^{-2}) than rest of the treatments.

Hoeing and pulling of weeds resulted in effective controlling grassy type of weeds and thereby recorded significantly lowest weed density. This might be observed due to hoeing and pulling of weeds and manual weeding created less weed density and weed crop competition for moisture, nutrients, space and CO_2. Although there are several ways to control weeds without the use of herbicides, mechanical hoeing is an attractive choice because these have a number of additional benefits (such as soil and water conservation) along with the provision of satisfactory and sustainable weed control. The similar results were observed by Mynavathi et al. [9] and Das et al. [8].

3.2.2 Effect of organic nutrient sources on weed composition and category wise weed density (No.m^{-2})

Among organic nutrient sources, crop supplied with 1/3 RDN each through FYM, VC and NC with biofertilizers showed lower weed density of monocot, dicot and total weeds as compared to other organic nutrient sources followed by application of 50 % RDN each through FYM and VC with biofertilizers at 120 days after transplanting during both the years of experimentation. The highest weed infestation of monocot, dicot and total weeds were recorded with application of 100 % RDN through FYM with biofertilizers as compared to other organic nutrient sources during both the years of experimentation. This might be due to appropriate combination of organic sources to quit germination of viable weed seed germinate slowly and suppress the weed by the crop canopy. Similar results observed by Kamble [10] and Ali et al. [11].

Among the different organic nutrient sources, application of 1/3 RDN each through FYM+ VC+ NC with biofertilizers reduced grassy weeds, broad-leaved weeds, sedges and total weed density significantly than the rest of treatments during both the years. This might be due to application of FYM significantly increased the weed population. The similar results were observed by Ali et al. [11] and Kadu et al. [12].

3.2.3 Effect of non-chemical weed control modules on total dry matter of weeds (g m^{-2})

The weed dry matter at 120 DAT was significantly influenced due to different non-chemical weed control moduless at all the stages of observations during both the years. The highest weed biomass was recorded during both the years in weedy check. Significantly the lowest weight of dry matter of weed was recorded in weed free treatment over the rest of treatments. The second best treatment was hoeing and pulling of weeds having the lowest weight of dry matter of weed. This might be due to intensive mechanical operation, which brought the weed seeds remained in sub-surface and failed to germinate because of unfavorable condition. The highest weed intensity and biomass in weedy check treatment is might be due to its dominance in utilizing sunlight, moisture and CO_2 over plants resulting in accumulation of more dry matter by weeds and there by absorption of nutrients from soil. The similar results were observed by Mynavathi et al. [9].

3.2.4 Effect of organic nutrient sources on total dry matter of weeds (g m^{-2})

The weed dry matter at 120 DAT was significantly differed due to different application of organic nutrient sources during the both the years.

Treatment 50% RDN each through FYM and VC with biofertilizers registered significantly lowest weed dry matter over application of 100 % RDN through FYM with biofertilizers, however rest of organic treatments found at par with each other in respect of dry matter. The maximum weed dry matter was noticed in treatment 100% RDN through FYM with biofertilizers and it was significantly higher over all rest of the treatments. This might be due to increased organic matter which helps to supplied nutrient through FYM crops as well as weeds and application of FYM significantly increased the weed population. The similar results were observed by Aggarwal and Ram [13], Ali et al. [11] and Kadu et al. [12].

3.2.5 Interaction effect of non-chemical weed control modules and organic nutrient sources on total dry matter of weeds (g m^{-2})

Weed control treatments interacted significantly with organic nutrient sources for weed dry matter accumulation at 120 DAT during 2017 and 2018 Table 3b and 3c. Under weedy check, application of 50% RDN each through FYM and NC with biofertilizers resulted in significantly higher dry matter over rest of combinations; however it was at par with treatments 100 % RDN through FYM with biofertilizers, 100% RDN through VC with biofertilizers and 50% RDN each through VC and NC with biofertilizers respectively under weedy check during 2017. In 2018, significantly higher dry matter recorded under weedy check with treatment 1/3 RDN each through FYM, VC and NC with biofertilizers then rest of combinations however dry weight of weed at par with 50% RDN each through FYM and VC with biofertilizers to 50% RDN each through VC and NC with biofertilizers under weedy check. The weed dry weight was significantly less under weed free treatment with 100% RDN applied through VC with biofertilizers (3.32 g m^{-2}) than rest of treatment combination and found at par with weed free treatment with organic sources 50% RDN each through FYM and VC with biofertilizers to 1/3 RDN each through FYM, VC and NC with biofertilizers during 2017. In 2018, the weed dry weight was significantly less under weed free treatment with 50% RDN applied each through VC and NC with biofertilizers (3.96 g m^{-2}) than rest of treatment combinations and found statistically at par with weed free treatment with organic sources treatments of 50% RDN each through FYM and VC with biofertilizers to 1/3 RDN each through FYM, VC and NC with biofertilizers. Amongst the weed control treatment *gliricidia* leaf mulching @ 5 t ha^{-1} to hoeing and pulling of weeds with application of 100% RDN through VC with biofertilizers recorded minimum dry matter than rest of combinations, however at par with all treatments of organic sources during 2017. In 2018, amongst the weed control treatment *gliricidia* leaf mulching @ 5 t ha^{-1} to hoeing and pulling of weeds with application of 50 % RDN each through FYM and VC with biofertilizers recorded minimum dry matter of weed than rest of combinations except treatment 100 % RDN through VC with biofertilizers, 50 % RDN each through FYM and VC with biofertilizers to 1/3 RDN each through FYM, VC and NC with biofertilizers where it was at par.

Table 1. Weed composition showing monocot dicot and total weeds influenced by different treatments (No.m^{-2}) (120 DAT)

Treatments		Weed composition (No.m^{-2})					
		2017			2018		
		Monocots	Dicots	Total	Monocots	Dicots	Total
A. Non-chemical weed control modules							
W_1 :	GLM @ 5 t ha^{-1}	4.95 (23.62)	5.24 (26.52)	7.21 (51.05)	4.92 (23.38)	5.05 (24.57)	7.11 (49.71)
W_2 :	Mulch (soybean straw) @ 5 t ha^{-1}	4.96 (23.71)	5.28 (26.86)	7.26 (51.90)	4.94 (23.52)	5.15 (25.67)	7.20 (50.86)
W_3 :	Hoeing and pulling of weeds	3.51 (11.36)	4.05 (15.48)	5.34 (27.55)	3.63 (12.21)	3.80 (13.52)	5.32 (27.45)
W_4 :	Weedy check	7.70 (58.86)	7.68 (58.95)	10.87 (118.05)	7.91 (62.33)	7.80 (61.14)	11.31 (128.76)
W_5 :	Weed free	1.82 (2.34)	1.93 (2.75)	2.47 (5.15)	1.84 (2.41)	2.02 (3.16)	2.56 (5.64)
B. Organic nutrient sources							
O_1 :	100 % RDN (FYM) + BF	4.76 (26.25)	4.97 (27.77)	7.15 (59.09)	4.86 (27.60)	4.89 (27.55)	7.19 (61.43)
O_2 :	100 % RDN (VC) +BF	4.57 (23.60)	4.76 (25.09)	6.54 (49.15)	4.62 (24.08)	4.68 (24.47)	6.59 (50.10)
O_3 :	100 % RDN (NC) +BF	4.52 (22.93)	4.81 (25.61)	6.53 (19.01)	4.53 (22.97)	4.75 (25.29)	6.56 (49.61)
O_4 :	50:50 % RDN (FYM+VC) +BF	4.52 (23.15)	4.81 (25.55)	6.53 (49.17)	4.54 (23.27)	4.70 (24.54)	6.53 (49.09)
O_5 :	50:50 % RDN (FYM+NC) +BF	4.63 (24.65)	4.90 (26.87)	6.64 (51.05)	4.75 (26.37)	4.88 (26.73)	6.80 (54.45)
O_6 :	50:50 % RDN (VC+NC) +BF	4.63 (24.53)	4.88 (26.62)	6.58 (49.75)	4.72 (25.75)	4.77 (25.55)	6.66 (51.98)
O_7 :	1/3 RDN (FYM + VC + NC) +BF	4.48 (22.73)	4.73 (25.28)	6.45 (47.95)	4.53 (23.38)	4.66 (25.15)	6.59 (50.74)
	Mean	4.59 (23.98)	4.84 (26.11)	6.63 (50.74)	4.65 (24.77)	4.76 (25.61)	6.70 (52.48)

**Figures in the parenthesis are actual observed values. Transformed value √ x+1*

3.2.6 Effect of non-chemical weed control modules on weed index and weed control efficiency

Significantly the highest weed control efficiency observed under weed free treatment but among the weed management practices significantly highest weed control efficiency was recorded under hoeing and pulling of weeds at all the stages of observations during both the years than *gliricidia* leaf mulching @ 5 t ha^{-1} and mulch- soybean straw @ 5 t ha^{-1}. This might be due to non-chemical weed control modules *viz.* hoeing and pulling of weeds during the period of crop weed competition which resulted lesser monocot, dicot as well as total weed density and it resulted greater weed control efficiency. Weedy check recorded minimum weed control efficiency owing to uncontrolled conditions favoured luxurious weed growth leading to increased weed dry matter. Similar results were also observed by Aggarwal and Ram [13]. Among the weed management practices, lowest weed index was observed under hoeing and pulling of weeds as compared to rest of the treatments during both the years. The highest weed index was observed in weedy check treatments during both years of experimentation. This might be due to non-chemical weed control modules *viz.* hoeing and pulling of weeds during the period of crop weed competition which resulted lesser monocot, dicot as well as total weed intensity and resulted greater weed index and the effective control of weed and frequency of weed control treatments might have enabled the crop to utilize available resources like light, nutrients, moisture and space resulting in higher yield. Might be attributed lower weed index represents here the less yield losses due to weed result in these treatments Similar findings were observed by Mansuri et al. (2011).

Table 2. Category wise weed density (No. m^{-2}) as influenced by non-chemical weed control modules and organic nutrient sources

Treatments	Density of weeds (No. m^{-2})							
	Grassy weeds		BLW		Sedges		Total	
	2017	2018	2017	2018	2017	2018	2017	2018
A. Non-chemical weed control modules								
GLM @ 5 t ha^{-1}	4.06 (15.62)	4.02 (15.29)	5.28 (26.90)	5.18 (25.90)	3.13 (8.52)	3.15 (8.52)	7.21 (51.05)	7.11 (49.71)
Mulch (soybean straw) @ 5 t ha^{-1}	3.99 (15.05)	3.97 (14.86)	5.36 (27.86)	5.28 (27.00)	3.19 (9.00)	3.13 (9.00)	7.26 (51.90)	7.20 (50.86)
Hoeing and pulling of weeds	2.72 (6.40)	2.83 (7.02)	4.13 (16.14)	4.00 (15.14)	2.44 (5.00)	2.50 (5.29)	5.34 (27.55)	5.32 (27.45)
Weedy check	6.67 (44.00)	6.92 (47.67)	7.61 (58.52)	8.23 (67.52)	3.89 (13.90)	3.93 (14.05)	10.87 (118.05)	11.31 (128.76)
Weed free	1.28 (0.63)	1.30 (0.70)	1.94 (2.80)	2.04 (3.22)	1.29 (1.71)	1.62 (1.71)	2.47 (5.15)	2.56 (5.64)
S.Em (±)	0.14	0.20	0.15	0.23	0.14	0.09	0.17	0.30
CD @ 5 %	0.47	0.67	0.50	0.77	0.48	0.29	0.56	0.99
Organic nutrient sources								
100 % RDN (FYM) + BF	4.06 (19.65)	4.12 (20.67)	5.29 (31.11)	5.30 (32.63)	3.22 (7.87)	3.23 (8.13)	7.15 (59.09)	7.19 (61.43)
100 % RDN (VC) +BF	3.71 (15.93)	3.76 (16.41)	4.76 (25.09)	4.82 (26.02)	2.75 (7.67)	2.84 (7.67)	6.54 (49.15)	6.59 (50.10)
100 % RDN (NC) +BF	3.67 (15.46)	3.68 (15.51)	4.81 (25.61)	4.87 (26.63)	2.73 (7.47)	2.81 (7.47)	6.53 (19.01)	6.56 (49.61)
50:50 % RDN (FYM+VC) +BF	3.66 (15.55)	3.67 (15.67)	4.81 (25.55)	4.82 (25.82)	2.76 (7.60)	2.84 (7.60)	6.53 (49.17)	6.53 (49.09)
50:50 % RDN (FYM+NC) +BF	3.77 (16.85)	3.88 (18.37)	4.84 (26.87)	4.99 (28.08)	2.72 (7.80)	2.87 (8.00)	6.64 (51.05)	6.80 (54.45)
50:50 % RDN (VC+NC) +BF	3.76 (16.60)	3.84 (17.55)	4.77 (25.75)	4.91 (27.30)	2.74 (7.67)	2.84 (7.80)	6.58 (49.75)	6.66 (51.98)
1/3 RDN (FYM + VC + NC) +BF	3.57 (14.33)	3.69 (15.58)	4.76 (25.15)	4.92 (27.83)	2.60 (7.33)	2.63 (7.33)	6.45 (47.95)	6.59 (50.74)
S.Em (±)	0.07	0.08	0.07	0.08	0.09	0.11	0.09	0.11
CD @ 5 %	0.24	0.27	0.21	0.25	0.30	0.33	0.30	0.34

Treatments	Density of weeds (No. m^{-2})							
	Grassy weeds		BLW		Sedges		Total	
	2017	2018	2017	2018	2017	2018	2017	2018
C. Interaction (A x B)								
Between two organic nutrient sources means at same level of non-chemical weed control modules means								
S.Em (±)	0.21	0.27	0.21	0.29	0.25	0.24	0.26	0.38
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS
Between two non-chemical weed control modules means at same level of organic nutrient sources means								
S.Em (±)	0.17	0.18	0.16	0.18	0.21	0.23	0.21	0.24
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS
Mean	3.74 (16.34)	3.81 (17.11)	4.87 (26.45)	4.95 (27.76)	2.79 (7.63)	2.87 (7.71)	6.63 (50.74)	6.70 (52.48)

Figures in the parenthesis are actual observed values. Transformed value √ x+1

Table 3a. Total weed dry matter (At 120 DAT), weed control efficiency (%) and weed index (%) as influenced by non-chemical weed control modules and organic nutrient sources

Treatments		Total weed dry matter (g m^{-2})		Weed control efficiency (%)		Weed index (%)		
		2017	2018	2017	2018	2017	2018	Pooled
A.	**Non-chemical weed control modules**							
W_1 :	GLM @ 5 t ha^{-1}	12.99 *(167.95)	14.23 (202.74)	57.61	60.78	18.45	12.78	15.50
W_2 :	Mulch (soybean straw) @ 5 t ha^{-1}	12.89 (165.24)	13.62 (185.11)	56.88	59.90	18.49	14.73	16.53
W_3 :	Hoeing and pulling of weeds	8.14 (65.29)	9.57 (91.95)	77.82	77.90	9.20	5.53	7.30
W_4 :	Weedy check	18.11 (326.86)	18.91 (357.32)	0.00	0.00	31.04	30.37	30.67
W_5 :	Weed free	3.49 (11.38)	4.09 (15.76)	97.08	94.67	0.00	0.00	0.00
	S.Em (±)	0.10	0.21	-	-	-	-	-
	CD @ 5 %	0.33	0.68	-	-	-	-	-
B.	**Organic nutrient sources**							
O_1 :	100 % RDN (FYM) + BF	11.41 (152.60)	12.89 (188.87)	50.70	51.77	21.01	18.35	19.62

Treatments		Total weed dry matter (g m^{-2})		Weed control efficiency (%)		Weed index (%)		
		2017	**2018**	**2017**	**2018**	**2017**	**2018**	**Pooled**
O_2 :	100 % RDN (VC) +BF	11.04 (146.07)	11.99 (167.20)	59.24	60.48	18.25	13.19	15.59
O_3 :	100 % RDN (NC) +BF	11.07 (145.67)	11.89 (166.17)	59.36	60.86	19.75	14.00	16.76
O_4 :	50:50 % RDN (FYM+VC) BF	11.06 (145.33)	11.88 (165.88)	59.23	61.26	4.01	4.48	4.26
O_5 :	50:50 % RDN (FYM+NC) +BF	11.11 (148.07)	12.03 (169.39)	57.61	57.13	11.67	10.47	11.05
O_6 :	50:50 % RDN (VC+NC) +BF	11.11 (147.67)	12.02 (169.62)	58.73	59.03	16.56	15.63	16.06
O_7 :	1/3 RDN (FYM + VC + NC) +BF	11.08 (146.00)	11.90 (166.93)	60.28	59.99	16.80	12.60	14.61
	S.Em (±)	0.04	0.15	-	-	-	-	-
	CD @ 5 %	0.14	0.49	-	-	-	-	-
C.	**Interaction (A x B)**							
Between two organic nutrient sources means at same level of non-chemical weed control modules means								
	S.Em (±)	0.14	0.39	-	-	-	-	-
	CD @ 5 %	0.27	0.50	-	-	-	-	-
Between two non-chemical weed control modules means at same level of organic nutrient sources means								
	S.Em (±)	0.10	0.36	-	-	-	-	-
	CD @ 5 %	0.16	0.53	-	-	-	-	-
	Mean	11.13 (147.34)	12.09 (170.58)	-	-	-	-	-

**Figures in the parenthesis are actual observed values. Transformed value √ x+1*

Table 3b. Interaction effect on total weed dry matter influenced by different non-chemical weed control modules and organic nutrient sources (2017)

Organic sources		Non-chemical weed control modules					
		GLM @ 5 t ha^{-1}	**Mulch (soybean straw) @ 5 t ha^{-1}**	**Hoeing and pulling of weeds**	**Weedy check**	**Weed free**	**Mean**
O_1 :	100 % RDN (FYM) + BF	13.70	12.77	8.25	18.22	4.12	11.41
O_2 :	100 % RDN (VC) +BF	12.82	12.92	8.04	18.11	3.32	11.04

Organic sources	**Non-chemical weed control modules**					
	GLM @ 5 t ha^{-1}	**Mulch (soybean straw) @ 5 t ha^{-1}**	**Hoeing and pulling of weeds**	**Weedy check**	**Weed free**	**Mean**
O_3 : 100 % RDN (NC) +BF	12.88	12.92	8.20	17.87	3.45	11.07
O_4 : 50:50 % RDN (FYM+VC) +BF	12.86	12.91	8.18	17.97	3.36	11.06
O_5 : 50:50 % RDN (FYM+NC) +BF	12.86	12.87	8.06	18.38	3.40	11.11
O_6 : 50:50 % RDN (VC+NC) +BF	12.91	12.94	8.06	18.24	3.40	11.11
O_7 : 1/3 RDN (FYM + VC + NC) +BF	12.94	12.92	8.16	17.95	3.40	11.08
Mean	12.99	12.89	8.14	18.11	3.49	11.13
	Between two organic nutrient sources means at same level of non-chemical weed control modules means			Between two non-chemical weed control modules means at same level of organic nutrient sources means		
S.Em (±)	0.14			0.10		
CD @ 5 %	0.27			0.16		

Table 3c. Interaction effect on total weed dry matter influenced by different non-chemical weed control modules and organic nutrient sources (2018)

Organic sources	**Non-chemical weed control modules**					
	GLM @ 5 t ha^{-1}	**Mulch (soybean straw) @ 5 t ha^{-1}**	**Hoeing and pulling of weeds**	**Weedy check**	**Weed free**	**Mean**
O_1 : 100 % RDN (FYM) + BF	16.76	15.09	10.85	17.44	4.31	12.89
O_2 : 100 % RDN (VC) +BF	13.89	13.66	9.37	18.86	4.16	11.99
O_3 : 100 % RDN (NC) +BF	13.73	13.26	9.34	19.00	4.12	11.89
O_4 : 50:50 % RDN (FYM+VC) +BF	13.88	13.25	9.08	19.13	4.03	11.88
O_5 : 50:50 % RDN (FYM+NC) +BF	13.94	13.46	9.60	19.17	4.00	12.03
O_6 : 50:50 % RDN (VC+NC) +BF	13.99	13.45	9.39	19.29	3.96	12.02
O_7 : 1/3 RDN (FYM + VC + NC) +BF	13.44	13.18	9.36	19.50	4.04	11.90
Mean	14.23	13.62	9.57	18.91	4.09	12.09
	Between two organic nutrient sources means at same level of non-chemical weed control modules means			Between two non-chemical weed control modules means at same level of organic nutrient sources means		
S.Em (±)	0.39			0.36		
CD @ 5 %	0.50			0.53		

Table 4. Nutrient removal (kg ha^{-1}) by weed as influenced by non-chemical weed control modules and organic nutrient sources at harvest

Treatments	Nutrient removal by weed (kg ha^{-1})					
	Nitrogen		Phosphorus		Potassium	
	2017	2018	2017	2018	2017	2018
A. Non-chemical weed control modules						
W_1 : GLM @ 5 t ha^{-1}	15.96	25.19	14.16	15.19	9.61	10.11
W_2 : Mulch (soybean straw) @ 5 t ha^{-1}	16.26	25.52	15.99	16.35	9.16	9.74
W_3 : Hoeing and pulling of weeds	7.92	8.07	14.71	15.90	8.73	9.41
W_4 : Weedy check	33.72	36.65	17.24	16.44	10.61	10.94
W_5 : Weed free	2.15	2.00	13.03	12.19	8.63	9.02
S.Em (±)	1.24	1.06	0.47	0.66	0.32	0.27
CD @ 5 %	4.05	3.46	1.55	2.17	1.05	0.88
B. Organic nutrient sources						
O_1 : 100 % RDN (FYM) + BF	19.81	24.47	14.04	14.67	8.88	9.84
O_2 : 100 % RDN (VC) +BF	13.81	18.32	14.58	14.90	8.95	9.26
O_3 : 100 % RDN (NC) +BF	13.78	17.97	14.52	15.23	9.06	9.42
O_4 : 50:50 % RDN (FYM+VC) +BF	13.61	18.02	16.98	16.48	10.45	10.71
O_5 : 50:50 % RDN (FYM+NC) +BF	14.27	18.03	15.52	15.35	9.63	10.11
O_6 : 50:50 % RDN (VC+NC) +BF	14.16	18.60	14.83	14.76	9.27	9.74
O_7 : 1/3 RDN (FYM + VC + NC) +BF	16.97	20.99	14.70	15.12	9.19	9.82
S.Em (±)	1.31	1.30	0.44	0.15	0.29	0.23
CD @ 5 %	4.05	4.01	1.36	0.48	0.89	0.71
C. Interaction (A x B)						
Between two organic nutrient sources means at same level of non-chemical weed control modules means						
S.Em (±)	2.91	2.78	1.02	1.10	0.63	0.53
CD @ 5 %	NS	NS	NS	NS	NS	NS
Between two non-chemical weed control modules means at same level of organic nutrient sources means						
S.Em (±)	2.86	2.81	0.98	0.86	0.60	0.49
CD @ 5 %	NS	NS	NS	NS	NS	NS
Mean	15.20	19.49	15.03	15.21	9.35	9.84

3.2.7 Effect of organic nutrient sources on weed index and weed control efficiency

Among the organic treatments, application of 100 % RDN through organic nutrient sources i.e. 1/3 RDN each through FYM, VC and NC with biofertilizers recorded highest weed control efficiency at all stages of observations during 2017 and at 60 and 90 DAT during 2018, respectively. Among the sources application of 100 % RDN through FYM with biofertilizers show lowest weed control efficiency in brinjal at all stages of observations during both the years. This might be due to FYM contains indigenous seed bank and also essential nutrients required for rapid weeds growth. Similar results were observed by Paikra (2005), Jangre (2009) and Kadu et al. [12]. Among the organic sources application of 50 RDN each through FYM and VC with biofertilizers recorded lowest weed index as compared to rest of the treatments. The highest weed index was noticed in 100 % RDN through FYM with biofertilizers treatments during both the years of experimentation. However, weed index followed just opposite trend of weed control efficiency. The reason attributed is the better growth of crop with more yield attributes and yield at optimum nutrient doses resulted luxuriant growth. Similar results were observed by Vidyasagar et al. [14].

3.3 Nutrient Removal by Weed (kg ha^{-1})

3.3.1 Effect of non-chemical weed control modules on nutrient removal by weed (kg ha^{-1})

Weed management practices significantly influenced the N, P, and K removal by weed at harvest. Among the different treatments the significantly lower N (2.15 and 2.00 kg ha^{-1}), P (13.03 and 12.19 kg ha^{-1}) and K (8.63 and 9.02 kg ha^{-1}) removal by weeds was observed in weed free treatment as compared to all other weed control treatments during 2017 and 2018, however hoeing and pulling of weeds with which K removal was at par during 2017 and 2018, respectively. As the weed growth increases, the nutrient removal by weed also increases and vice-versa. The luxuriant growth of weed suppresses crop growth and development, which ultimately reflected in removal of nutrient. Similar results were observed by Sunil et al. [15] and Deewan et al. [16].

3.3.2 Effect of organic nutrient sources on nutrient removal by weed (kg ha^{-1})

Among the organic nutrient sources the significantly lower value of N removal was observed in treatment where the crop is supplied with 50 % N each through FYM and VC with bio-fertilizers and 100 % RDN through NC during 2017 and 2018, respectively. In respect P removal by weed the significantly lower value was observed in treatment of 100 % RDN applied through FYM during 2017 and 2018, respectively while, significantly lower value of K removal was observed in treatment of 100 % RDN supplied though FYM during 2017 and 100 % RDN supplied though VC during 2018. Finding also confirm with the results of Sunil et al. [15] and Raj et al. [17]. The interaction between non-chemical weed control modules and organic nutrient sources on removal of nitrogen, phosphorus and potassium was found to be non-significant during both the years of experimentation.

4. CONCLUSION

On the basis of two-year experiment, it may be said that cultivation of *kharif* brinjal with non-chemical weed control modules of keeping the crop weed free up to 80 days after transplanting by adapting five hand weeding (at an interval of 15 days) or four mechanical (hoeing) intercultivation and pulling of weeds between the rows (20 days interval from 20 to 80 days after transplanting) and uses of 50 percent nitrogen (50 N kg ha^{-1}) each through farm yard manure and vermicompost with biofertilizers (*Azospirillum* and *PSB*) along with organic plant protection measures revealed appropriate organic package for greater productivity, fruit quality and sustaining soil health.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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