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Research Paper

Impact of integrated agro-technologies on the weeds and cured leaf yield of tobacco (*Nicotiana tabaccum*) in Southern India

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ABSTRACT

Field experiment was conducted during 2018–19 and 2019–20 at ICAR-National Institute for Research on Commercial Agriculture, Research Station Farm, Vedasandur to find out the effect of integrated agro technologies on the weeds including *orobanche,* yield and quality of chewing tobacco. The treatments comprised of main plots, viz. soil solarization and non-soil solarization and sub plots, viz. traditional nursery seedlings + furrow irrigation +100% recommended dose of fertilizer (RDF), traditional nursery seedlings + alternate furrow irrigation + 100% RDF, tray seedlings + furrow irrigation +100% RDF, tray seedlings + alternate furrow irrigation + 100% RDF, tray seedlings + alternate furrow irrigation + 80% RDN+100% RD of P&K. The experiment was conducted in a split plot design with 3 replications. Soil solarization reduced the monocot weed population by 30 to 39% over the non-soil solarization. The dry weight of monocot significantly reduced by 50 and 30% with 40 DAT and at harvest stage respectively with soil solarization as compared to non-soil solarization. Soil solarization significantly reduced the dry weight of dicot weeds by 78 and 91 % at 40 DAT and at harvest respectively over non-soil solarization. Soil solarization significantly reduced the dry weight of *orobanche* by 77 and 41% at 60 DAT and at harvest stage over non-soil solarization. It could be concluded that soil solarization efficiently reduced the monocot and dicot weeds including Orabanche. Tray seedlings planting + 100% RDF + furrow irrigation increased the cured leaf yield and net returns. The chewing quality was also found to be preferable. Tray seedlings planted + furrow irrigation + 100% RDF increased the net return by 18% over traditional nursery seedlings planted + furrow irrigation + 100% RDF. Though the net returns with respect to soil solarization was low, continuous soil solarization for 2 to 3 years could reduce the weed infestation which may increase cured leaf yield and net returns.

Key words: Soil solarization, weeds, *orobanche,* chewing tobacco.

Chewing tobacco in Tamil Nadu is one of the commercial crops grown in an area of 15,000 ha. The weeds and *orobanche* are the major constraints in chewing tobacco productivity, as expensive time consuming and causing severe yield losses when failing to ensure an adequate management. The major dicot weeds in tobacco are *Trianthema portulacastrum, Boerhevia diffusa* and *Parthenium hysterophorus*. The monocot weeds were mostly grasses. These weeds grow faster than tobacco in nursery and main field and suppress the growth and yield of tobacco. Elmore (1991) reported that many weeds are susceptible for soil solarization. The modification of thermal range of the top soil layer, makes the substrate hot enough to devitalize weed seeds and nematodes, along with plant pathogenic fungi and bacteria (Candido *et al.,* 2011). Water use (WU) of weeds is one of the most critical pieces of information underlying this assessment and the subsequent management of weeds. Owing to their superior ability for soil water exploration (Stuart *et al.,* 1984), greater effective root zone and soil volume per plant, rapid development of extensive root systems, greater resource affinity, and higher tolerance to climatic variation than most crops (Zimdahl, 2018), weeds often demand more water than many crops. *Orobanche* is a root parasite that grows in tobacco . The root parasite suppresses the tobacco crop by absorbing water and nutrients from the crop. The broom rapes interfere with water and mineral uptake and are responsible for both qualitative and quantitative damages that can reach 33% in tobacco. In Tamil Nadu the yield loss of tobacco due to *Orabanche* is more than 50%. *Orobanche* spp. are not usually amenable to control by persistent selective herbicides, since herbicides cannot

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differentiate between crop and the parasite, except on herbicide-tolerant transgenic crops (Surov *et al.,*1997). The poly tray method of raising seedlings without soil has many advantages (Koller *et al.,* 2004). Transplanting traditional nursery seedlings in the main field needs gap filling for 1 to 2 times in tobacco. Poly tray seedlings performance was better and reduced the gap filling (Subbiah *et al.,* 2018). The furrow irrigation significantly produced greater yield, mean cured leaves weight and irrigation water use efficiency (IWUE) as compared with drip irrigation in burley tobacco. (Maria and Youssef, 2018). Soil solarization reduced the native soil microbial populations since the solarized soils had a lower occurrence of bacteria and fungi than the non-solarized soils (Omotayo and Eegunranti, 2023). In FCV tobacco Integrated nutrient management practices significantly increased the cured leaf yield (Krishna reddy *et al.,* 2009) Hence with the above back ground the experiment was conducted to find out the effect of integrated agro technologies on the management of weeds and *orobanche* for enhanced tobacco production and economic returns.

MATERIALS AND METHODS

A field experiment was conducted during 2018–19, 2019–20 in farm lands of Vedasandur, Tamil Nadu at India (Latitude 10° 32'N longitude 77° 57'). The soil was sandy with a *p*H of 8.3, Soil OC (0.35%), low in soil available nitrogen (210 kg/ha) and P (6.5 kg/ha), medium in available K (275 kg/ha). The treatments comprised of main plots, viz. soil solarization and non-soil solarization subplots, viz. traditional nursery seedlings + furrow irrigation +100% RDF, traditional nursery seedlings + alternate furrow irrigation + 100% RDF, tray seedlings + furrow irrigation + 100% RDF, tray seedlings + alternate furrow irrigation +100% RDF, tray seedlings + alternate furrow irrigation + 80% RDN + 100% RD of P and K. The experiment was conducted in a split plot design with three replications. Soil solarization was done with transparent polythene sheet with 100µ thickness during summer months from April to June in the main field. The field was irrigated 3 days before the solarization. Chewing tobacco seedlings were raised in a raised bed of dimension of 1.5 m with a width of 1.0 m. The height of the raised bed was 10 cm. Before preparing the bed the field was ploughed 3 times and the seed bed area was made free from clots and stones. After preparing the seed beds *rabbing* was done with crop residues to kill the pupa of the insect, harmful pathogens and nematodes. Farmyard manure 10 kg with 80 gm single super phosphate was applied for 1.5 m^2 bed and mixed in the top layer of the soil. Chewing tobacco seeds 1.5 gm is mixed with handful of sand. The seeds were mixed in the top layer of the soil. Iron pipe of 2'' diameter was rolled on the top of the seed bed so that the tiny tobacco seeds will have contact with the soil. The seed beds are covered with paddy straw to protect the germinating seeds from hot sunlight and beating rains. Irrigation to the beds was given through showers. The seed beds needs 5-6 shower irrigation per day for good germination of seeds. The irrigation water having < 500 ppm of TSS was used for the nursery. The 45 days old seedlings are planted in the main field. The 15 days old traditional nursery seedlings from the nursery beds were transplanted in the trays and kept in the shade net for 30 days. The tray medium used was cocopeat + vermicompost in 1:1 ratio. The seedlings of 45 days old are transplanted in the main field. The main field is ploughed three times by tractor drawn cultivator, ridges and furrows are formed at 90 cm spacing. Phosphorous @ 22 kg/ha in the form of single Super Phosphate (SSP) mixed with 4 times Farm Yard Manure was spot applied. The chewing tobacco seedlings are planted at a spacing of 75 cm in the ridges. The field is kept moist during transplanting. Life irrigation is given on the second day after transplanting (DAT). Earthing up operation was done on 40th DAT and the first dose of 50% N as per treatment was spot applied and ridges and furrows are reformed. The experiment crop was topped by keeping 12 leaves on the plants. At 120 days the crop was harvested by stalk cut method during evening hours to avoid leaf damage and left as such in the field for wilting. The stalk cut plants of 40–50 numbers were heaped on the next day evening hours the butt ends of the two plants are tied with polythene thread and hung in the bamboo scaffolds for sun drying. The harvested plants are sun dried for 3 weeks. During the 3 weeks period the plants were turned once in three days for complete drying. The dried plants are bulked in the bulking shed. The bulking for fermentation process was done in square shape with a length of 6′ × 6′ × 10′ length, width and height. Palmyrah mat was used to cover the bulk to avoid moisture loss from the tobacco leaves and to protect the external heat entering in the fermentation process. During fermentation to avoid excess heat the bulks are rebulked in another place. After three weeks the leaves are stripped and the cured leaves are graded as *rasi* long, *rasi* medium, rasi short and *Kurz*. The yield of *rasi* long was termed as First Grade Leaf Yield (FGLY). The FGLY and the other grades leaves viz. *rasi* medium, *rasi* short and kuruz are termed as Total Cured Leaf Yield (TCLY). The cured leaf yield was recorded in kg/ha. The composite sample leaves in each treatment are collected for chewing test. Three testers were given the composite sample leaves and score was recorded. The various quality characters tested are given in the Table 1.

Table 1. Chewing quality score card

Character	Maximum score	Sub-division categories	Score
Body	10	Heavy	10
		Medium	5
		Low	2
Aroma	10	Good	10
		Very fair	7
		Fair	5
		Bad	2
Whitish Incrustation	10	Heavy	10
		Medium	5
		Low	2
Taste	10	Sweet	10
		Slightly Bitter	5
		Bitter	2
Pungency	10	High	10
		Medium	5
		Low	2
Saliva secretion	10	Good	10
		Medium	5
		Low	2
Retention of pungency	10	5 min	10
		3 min	6
		1 min	2
Stiffness in the mouth	10	Good	10
		Medium	5
		Low	2
Total	80	Rating: > 60 Preferable	

A score of > 60 would be preferable for chewing purpose. Source: Palanisamy and Nagarajan (1998).

The post harvest soil samples were collected in each treatment at a depth of 0–22.5 cm at all the three replication for chemical analysis as per the standard procedure. The soil samples were analysed for soil OC, available P and available K. Five plants were randomly selected from each plots for measurement of chewing tobacco growth characters. The chewing tobacco growth characters were recorded at 60 days in the crop development stage (60 days) and at late season stage at 120 days in all the treatments and replication. The third leaf after topping was selected and labeled. The third leaf was measured using a scale of 1.0 m length from the bottom of the leaf to leaf blade tip. To record the leaf width the middle portion of the leaf was selected and measured. The measurement on growth characters was pooled and the mean was recorded for each treatment as replication wise. The leaf measured during 60 DAT was measured at 120 DAT also.

Soil samples from the rhizosphere were collected from each replication of treatments at 60 DAT and homogenized. One gram of soil from each replication was serial diluted by mixing the soil (1g) in 9 ml sterile distilled water thus it became 10^{-1} and further dilutions made up to 10^{-5}. One ml of sample from each 10^{-2}, 10^{-3} and 10^{-5} dilution was drawn separately and plated on Kenknight and Munaier's agar, Potato dextrose agar and nutrient agar to isolate actinomycetes , fungi and bacteria respectively. The plates were kept at room temperature. Observations on colony counts were made 48 h, 72 h and 96 h after incubation for bacteria, fungi and actinomycetes respectively. The population of each organism was expressed in Colony forming unit (CFU) per gram.

The data was subjected to split spot analysis. Data analysis for all the observation of chewing tobacco leaf length, leaf width, stem girth, First Grade Leaf Yield, Total cured leaf yield, weed density, dry and fresh weight of weeds were analyzed using the software of Sheoran *et al.,* (1998). The analysis of variance (ANNOVA) was used to test the various growth characters and yield. Weed population was determined by counting and recording the weed species within the quadrate. Weed species were identified by as per the Bulletin of Naidu (2012). Weeds species were pooled together for calculating the weed density. The mean weed density collected in three places in the treatment were weighed and the fresh weight of the weeds was recorded. The weeds were shade dried followed by drying in an oven and the dry weight was recorded and expressed in g/m^2.

The total rainfall received during 2018–19 and 2019–20 crop season was 262.2 and 459.2 mm, respectively.

RESULTS AND DISCUSSION

Effect on weeds

Soil solarization significantly reduced the number of monocot weeds/m^2. There was reduction of 30% of monocot weeds with soil solarization as compared to the non solarization at 40 DAT. At harvest stage also soil solarization significantly reduced the number of monocot weeds / m^2 by 39% over the non-soil solarization (Table 2). The dry weight of monocots also significantly reduced by 50 and 30% with 40 DAT and at harvest stage respectively with soil solarization as compared to non soil solarization.

Soil solarization significantly reduced the dicot weed population by 32 and 30% at 40 DAT and at harvest stage respectively over non-soil solarization. The dicot weed population reduced at harvest stage as compared to the 40 DAT stage. This could be attributed to the earthing up operation taken up at 45 DAT and shade effect of tobacco leaves. Soil solarization significantly reduced the dry weight of dicots by 78 and 91% at 40 DAT and at harvest stage respectively over the non soil solarization. The increased temperature during soil solarization during summer months resulted in mortality rate of the weed seed bank. Soil solarization strongly reduced the weed density and dry weight (Vencenzo *et al.*, 2001).

Tray seedlings or traditional nursery seedlings planted + alternate furrow irrigation irrespective of fertility levels significantly reduced the dry weight of dicot weeds. The dry weight of dicot weeds ranged from 5.02 to 5.49 and 11.00 to 11.40 g/m^2 at 40 DAT at harvest stage respectively (Table 2). The dry weight of monocots significantly reduced with tray seedlings or with traditional nursery seedlings planted + alternate furrow irrigation irrespective of fertilizer level. The dry weight ranged from 2.63 to 3.02 g /m^2 at 40 DAT and 1.47 to 1.63 g/m^2 at harvest stage.

Planting tray seedlings or traditional nursery seedlings with alternated furrow irrigation irrespective of fertility levels significantly reduced the weed population and dry weight of dicot weeds 40 DAT and at harvest stage. Mohammad fawad *et al.,* (2022) reported an increased irrigation interval reduced the weed density and dry weight. Chowdhury *et al.,* (2017) reported that there was a significant reduction in weed dry weight with reduced irrigation level, which may be due to the fact that higher irrigation level can encourage weeds to emerge early and provide better growth conditions. The decrease in the dry weight of total weeds could be due to the reduction in weed growth as an adaptive strategy in response to water deficit (Gonçalves *et al.,* 2018) .

Effect on Orobanche

Soil solarization significantly reduced the dry weight of *orobanche* by 77 and 41 % at 60 DAT and at harvest stage over non soil solarization. The increase in temperature during soil solarization increased the seed mortality rate of *orobanche* thereby reduction in *orobanche* population and dry weight. Rosario *et al.,* (2015) reported that in one single cycle of soil solarization the seed bank mortality of *orobanche* spp. accounted for 99% of viable seeds.

Traditional nursery seedlings or tray nursery seedlings planted + furrow irrigation + 100% RDF significantly reduced the dry weight of *orobanche*. The dry weight of

Table 2. Effect of agro-technologies on the monocot weeds in chewing tobacco

Treatment	No. of Monocot weeds no./m^2		Monocot weed dry weight (g/m^2)	
	At 40th DAT	At harvesting	At 40th DAT	At harvesting
Main plot				
Soil solarization	4.20	1.97	2.39	1.60
Non-soil solarization	6.03	3.21	4.75	2.29
SEm±	0.24	0.13	0.19	0.15
CD (P=0.05)	0.89	0.47	0.71	0.56
Sub-plot				
Traditional nursery seedlings + furrow irrigation + 100% RDF	5.44	2.65	3.92	2.81
Traditional nursery seedlings + alternate furrow irrigation + 100% RDF	5.09	2.41	3.72	1.63
Tray seedlings + furrow irrigation + 100% RDF	5.44	2.80	4.69	2.65
Tray seedlings + alternate furrow irrigation + 100% RDF	5.00	2.56	2.90	2.21
Tray seedlings + alternate furrow irrigation + 80% RDN+ 100% RD of P and K	5.00	2.53	2.63	0.47
SEm±	0.14	0.17	0.42	0.45
CD (P=0.05)	0.40	NS	1.19	1.29

orobanche ranged between 0.22 to 0.27 kg /m^2 and 0.26 to 0.45 kg/m^2 during 60 DAT and at harvest stage respectively (Table 3).

Effect on growth and yield

Soil solarization significantly increased the leaf length and leaf width by 13 % at harvest as compared to the non soil solarization. Soil solarization significantly increased the FGLY by 26 % over non soil solarization. The FGLY recorded with soil solarization and non soil solarization was 2849 and 2258 kg /ha respectively (Table 4). The higher leaf length, leaf width increased the FGLY. Soil solarization significantly increased the TCLY by 19 % over the non soil solarization. The highest leaf length, leaf width and FGLY increased the TCLY. Soil solarization causes physical, chemical and microbiological modification with

Table 3. Effect of agro-technologies on the dicot weeds and *Orabanche* in chewing tobacco

Treatment	No of dicots at (g/m^2)		Dicot weed dry weight (g/m^2)		*Orobanche* dry weight (g/m^2)	
	At 40th DAT	At harvesting	At 40th DAT	At harvesting	At 60 DAT	At harvesting
Main plot						
Soil solarization	3.83	1.76	2.37	2.20	134	234
Non-soil solarization	5.66	2.52	10.83	25.09	570	389
SEm±	0.06	0.07	1.48	6.78	10	13
CD (P=0.05)	0.28	0.26	5.50	18.34	30	48
Sub plot						
Traditional nursery seedlings + Furrow irrigation + 100% RDF	5.98	2.14	6.34	18.90	274	452
Traditional nursery seedlings + alternate furrow irrigation + 100% RDF	4.19	1.78	5.23	11.14	720	611
Tray seedlings + Furrow irrigation + 100% RDF	5.95	2.19	7.19	17.95	221	267
Tray seedlings + alternate furrow irrigation + 100%RDF	4.45	1.63	5.49	11.40	483	632
Tray seedlings + alternate furrow irrigation + 80% RDN + 100% RD of P and K	4.14	1.60	5.02	11.00	490	642
SEm±	0.15	0.09	0.03	1.16	90	49
CD (P=0.05)	0.43	0.31	1.00	3.60	320	141

Table 4. Effect of agro-technologies on the growth and yield of chewing tobacco

Treatment	Leaf length (cm)	Leaf Width (cm)	FGLY (kg/ha)	TCLY (kg/ha)	Chewing quality (out of 80)	Gross returns (₹/ha)	Net returns (₹/ha)	Benifit: cost
Main-plot								
Soil solarization	78.3	42.1	2,849	3370	76	207,005	51,098	1.33
Non-soil solarization	69.0	37.1	2,258	2839	70	175,291	57,434	1.49
SEm±	0.31	0.42	55.9	85.3	-	10,570	2,100	0.03
CD (P=0.05)	1.17	1.56	207.9	317.20	-	31,700	6,300	0.12
Sub-plot								
Traditional nursery seedlings + Furrow irrigation +100% RDF	77.1	42.2	2,646	3167	76	197,384	63,577	1.48
Traditional nursery seedlings + alternate furrow irrigation + 100% RDF	71.1	37.1	2,410	2957	74	183,465	49,658	1.37
Tray seedlings + Furrow irrigation + 100% RDF	81.7	45.9	2,871	3439	78	214,953	75,146	1.54
Tray seedlings + alternate furrow irrigation + 100% RDF	73.1	37.9	2,518	3032	70	188,183	49,376	1.36
Tray seedlings + alternate furrow irrigation + 80% RDN + 100% RD of P and K	68.4	34.9	2,198	2802	66	171,754	33,572	1.25
SEm±	1.06	1.06	57.0	71.1	-	6,459	3,458	0.05
CD (P=0.05)	3.03	3.04	163.6	204.1	-	17,560	10,569	0.19

FGLY, First grade leaf yield; TCLY, total cured leaf yield.

in the soil, so avoiding the creation of a biological vacuum, stimulating root growth, increasing crop yield (Stapleton and DeVay, 1984). Preferable chewing quality more than 60 score was observed with both soil solarization and non soil solarization treatment.The scores varied between 70 to 76.

Tray seedlings planted + furrow irrigation + 100% RDF significantly increased the leaf length by 6 % and leaf width by 9 % as compared to the traditional nursery seedlings planted + furrow irrigation + 100% RDF. Tray seedlings had more fibrous roots resulted in increased absorption of nutrients thereby higher leaf length and width. Polytray seedlings significantly increased the growth attributes and total cured leaf of chewing tobacco when FYM, sheep manure, vermicompost with 25:75 or 50:50 combinations with cocopeat as compared to traditional nursery seedlings (Kumaresan *et al.,* 2020). Tray seedlings + alternate furrow irrigation + 80% RDN + 100% RD of P and K recorded a lower leaf length and width. The reduction in 20% of RDN could be attributed for the decreased leaf length and width. Tray seedlings planted + furrow irrigation + 100% RDF significantly increased the FGLY as compared to the traditional nursery seedlings + furrow irrigation + 100% RDF. The FGLY increased by 9 % with tray seedlings planted + furrow irrigation + 100% RDF as compared to traditional seedlings planted + furrow irrigation + 100% RDF. The higher moisture content in the soil increased the FGLY. Kumaresan *et al.,* (2008) reported that 100% ETc of irrigation water is essential for higher cured leaf yield. The tray seedling planted +alternate furrow irrigation + 80% RDN + 100% RD of P and K recorded the lowest FGLY. The reduction of N to 20% could be attributed for the lesser FGLY.

Tray seedlings planted + furrow irrigation + 100% RDF significantly increased the TCLY by 9 % over traditional nursery seedlings planted + furrow irrigation + 100% RDF. Tray seedlings planted+ alternate furrow irrigation + 80% RDN + 100% RD of P and K recorded a lower TCLY. The lesser leaf length, leaf width and FGLY could be attributed for lower TCLY. Preferable chewing quality more than 60 score was observed with all the agronomic management treatments. The scores varied between 66 to 78.

Economics

Soil solarization significantly increased the gross return by 18% over the non soil solarization. The higher FGLY, TCLY and the price realized could be attributed for higher gross return. Tray seedlings planted + furrow irrigation + 100% RDF significantly increased the gross return by 8 % over traditional nursery seedlings planted + furrow irrigation + 100% RDF. The higher FGLY, TCLY and the price realized could be attributed for higher gross return.

Soil solarization decreased the net return by 12 % over non soil solarization. The higher cost of the polythene sheet decreased the net return. It is observed that in the third year the dicot weeds and monocots weeds were reduced to the tune of 100% in the maize crop. Soil solarization continuously for 2 years reduced the monocot as well as dicot weeds as compared to non soil solarization. The net return was higher with non soil solarization (₹57434/ha).Tray seedlings planted + furrow irrigation + 100% RDF increased the net return by 18 % over traditional nursery seedlings planted + furrow irrigation + 100% RDF. The higher FGLY and TCLY increased the net return.

Benefit: cost ratio was lower with soil solarization (1.33) and higher with non soil solarization (1.49). The higher cost of cultivation resulted in lower benefit: cost ratio. The benefit: cost ratio with tray nursery seedlings planted and traditional nursery seedlings planted + furrow irrigation + 100% RDF are comparable.

Residual soil fertility status

The soil OC% and soil available P was not significantly influenced by the solarization treatments. There was an improvement in the soil OC% and available P over the initial status in all the treatments. The addition of organic manure basally and addition of fertilizers could be attributed for the improvement. The available K decreased with the treatments as compared to the initial K status. The crop uptake and K fixation could be attributed for the lower K values in the treatment.

Microbial population

The fungi population was higher in non soil solarization plot as compared to non soil solarization. Similar trend was noticed with bacterial population also (Table 5). The actinomycetes population was little higher with soil solarization as compared to non soil solarization. The different agronomy practices, viz. furrow irrigation +100% RDF increased the fungi population. The bacterial population was higher with traditional nursery seedlings planted + furrows irrigation + 100% RDF. The higher moisture content in the furrow irrigation could be attributed for higher microbial population. Hackl *et al.,* (2005) found that soil moisture was an important driver of overall microbial activity. The fungal and bacterial dry weight varied significantly along gradients of moisture (Morris and Boerner, 1999).

Thus, it could be concluded that soil solarization efficiently reduced the monocot and dicot weeds including *Orabanche*. Tray seedlings planting + 100% RDF + furrow irrigation increased the cured leaf yield and net returns. The chewing quality was also found to be preferable. Though the net returns with respect to soil solarization was low,

Table 5. Effect of agro-technologies on the residual soil fertility and microbial population.

Treatment	Soil OC%	Available P (kg/ha)	Available K (kg/ha)	Fungi (CFU/g)	Bacteria (CFU/g)	Actinomycetes (CFU/g)
Main plot						
Soil solarization	0.40	7.57	186.8	54.8	557.4	38.9
Non Soil solarization	0.43	7.17	210.8	173.4	1174.7	26.6
SEm±	0.01	0.01	8.60	31.40	30.6	2.80
CD (P=0.05)	NS	NS	22.1	100.2	98.2	9.60
Sub plot						
Traditional nursery seedlings + Furrow irrigation + 100% RDF	0.45	7.61	197.5	146.7	1456.7	35.7
Traditional nursery seedlings + alternate furrow irrigation + 100% RDF	0.36	7.88	190.9	190.1	850.1	38.9
Tray seedlings + Furrow irrigation + 100% RDF	0.45	6.42	177.6	176.7	726.7	27.1
Tray seedlings + alternate furrow irrigation + 100% RDF	0.38	7.39	172.6	150.2	596.7	35.8
Tray seedlings + alternate furrow irrigation + 80% RDN + 100% RD of P and K	0.44	7.66	196.7	106.7	700.1	26.3
SEm±	0.01	0.30	8.89	12.64	31.5	3.6
CD (P=0.05)	0.03	0.90	22.80	41.20	100.6	10.8

continuous soil solarization for 2 to 3 years could reduce the weeds including *orobanche*, thereby increased cured leaf yield and net returns.

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