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Scaling-up of toria (*Brassica campestris*) productivity using diverse agro-techniques in eastern Himalayan region

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ABSTRACT

Field experimentation on toria (*Brassica campestris* L.) was carried out with the major objective of utilizing the fallow land after rainy season by following suitable management practices in the region. Results revealed that under conventional tillage, roots were 39.1% longer and 36.8% heavier biomass, contrarily no tillage had 6% more soil organic carbon. The seed yield improved by 44.8% with minimum tillage over no tillage. Crop sown on 15 October obtained 16.9-47.6% additional seed yield over before and after sown crops, but line sowing evidenced 22.1% higher seed yield than the broadcasting. Planting geometry with 30x15 cm noticed 3.1-32.9% more seed yield. Nitrogen application at 75 kg/ha had 5.3-47% improvement of seed yield, whereas nitrogen use efficiency was highest with 50 kg/ha. Phosphorus application at 50 kg/ha added 61.5% more yield, whereas phosphorus-use efficiency was highest at 25 kg/ha. Twice irrigation at 30 and 60 days after sowing (DAS) noticed 40.5% extra seed yield, contrary water-use efficiency was highest with single irrigation at 30 DAS over no irrigation. Hand weeding twice at 25 and 50 DAS supplemented the seed yield by 52.6% with 55.7% weed control efficiency over no weeding. Adoption of better package of practices in newer area under existing cropping system will play a key role in future yield improvement. Therefore, as per the resource availability feasible technologies may harness higher seed yield of toria in eastern Himalayas.

Key words: Geometry, Management practices, Nutrient management, Sowing window, Toria, Water management

In the eastern Himalayan region (EHR), the population growth is rapid and food demands are speedily increasing; but, large chunk of the area is under fallow after the rainy season crop. This pressurizing the growers to produce more food per unit area, with limited resources available at site (Choudhary *et al*. 2013). Though, the region receives ample rainfall, favourable climate, rich soil and plentiful natural resources to take more than one crops sequentially in a year. Plenty of moisture remains left in the soil after harvesting of rainy season crop, along with intermittent rainfall, to support a succeeding crop (Saha and Ghosh 2010). After rainy season crop, entire wet land, and upland can be potentially used for growing subsequent crop. Most of the farm land in the region is fragmented with undulated landscape; where, use of farm machinery, irrigation facilities and modern cultivation technologies have some limitations. Near the wet and terrace land have sufficient water sources, those water sources can be diverted and efficiently utilized for crop production. Such lands can be efficiently utilized for crop production to complement and support farm income along with better land utilization.

Rice-fallow cropping system can be substituted by introducing short duration oilseed crops like toria (*Brassica campestris* L.) to meet out the oil requirement of the region. This crop has the ability for early emergence and faster development than cereals (Choudhary *et al.* 2014a). It provides better smothering, which, prevents from soil erosion and reduction of weed density (Roshdy *et al*. 2008). Toria not only provide the additional yield, better land use efficiency but also help to improve the livelihood and nutritional security (Charak *et al*. 2006). Though, crop productivity largely depends on the use of quality seeds, and management practices, viz. sowing window, methods, nutrient, water and weed management etc (Choudhary *et al.* 2014a). These are comprehensive and influenced by several factors, of which, maintaining optimum plant populations is an important factor that contributes to higher yield with least cost involvement (Chopra and Chopra 2002). Each management practices have their own advantages and limitations, thus, in the present study, small scale field experiments on toria were evaluated to develop the best agronomic practices to obtain higher yield of toria in Arunachal Pradesh, EHR of India.

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MATERIALS AND METHODS

Field experiments were conducted during the post rainy season (Oct–March) of 2008–09, 2009–10 and 2010–11 at the Research Farm (27° 95′ N latitude; 94° 76′ E longitude; 662 m above MSL) of ICAR Research Complex for North Eastern Hilly Region, Basar, Arunachal Pradesh. The experimental site falls in humid sub–tropical climate. The daily temperature during the study period varied widely between minimum 5.5°C and maximum 32°C, received average annual rainfall of 2 450 mm and the monsoon months (June to September) receives more than 77% of the annual rainfall. The soil of the site was silty loam in texture, acidic in reaction (pH 5.3), 1.5% of organic carbon (Walkley and Black), 205.6 kg/ha of available nitrogen (alkaline permanganate N), 8.3 kg/ha of available phosphorus (Bray P) and 260 kg/ha of available potassium (neutral normal ammonium acetate K).

Small scale experiments were conducted to establish the effect of agronomic practices on seed yield of toria to support the decision of growers of the region to follow the suitable practices. During post rainy season toria (var. TS 38) was tested with different set of treatments in randomized block design and replicated to maintain error degree of freedom 12 or more, except for method of sowing. The experiments mainly consist of tillage, [conventional tillage (CT; one moldboard plough followed by one harrowing); minimum tillage (MT; one harrowing) and no tillage (NT)], sowing window (DOS; 1 October, 15 October and 30 October), sowing method (broadcasting and line sowing at 30 × 10 cm), planting geometry (30 × 10 cm; 30 × 15 cm; 45 × 15 cm and 45 × 20 cm), nitrogen regimes (N; 0, 50, 75 and 100 kg/ha) and phosphorus regimes (P; 0, 25, 50 and 75 kg/ha), water management, 5 cm of water was applied at each irrigation [no irrigation, one irrigation at 30 days after sowing (DAS) and irrigation twice at 30 and 60 DAS] and weed management (no weeding, one hand weeding at 25 DAS and twice hand weeding at 25 and 50 DAS).

During the experimentation, yield attributes and seed yield was recorded from net plot area of 2.4 m^2 (1.2 × 2.0 m). However, only seed yield along with necessary data were prioritized for interpretation to explain the effect of individual variables on seed yield. Under tillage experiment, root samples were collected carefully from the field at the time of flowering to obtain maximum root length and root dry weight from five marked plants. Soil organic carbon (SOC) was determined using the modified Walkley–Black method. The N and P removal was measured from the concentration of N and P in dry matter and multiplied with total dry matter production per unit area, but, N and P use efficiency was worked out with the ratio of N and P removal to the nutrients supplied. The agronomic efficiency was worked out by yield difference in treated and untreated plot to nitrogen applied. Crops were subjected to irrigation during 30 and 60 DAS with 5 cm depth with respect to treatments. The amount of rainfall received was considered as effective rainfall and soil moisture contribution from soil profile was also considered in total water use including volume of water irrigated. Weed count and sampling of weeds were done by using a quadrate size 0.25 × 0.25 m. The weed control efficiency (WCE) was worked out on the basis of reduction of weed dry weight in weeded plot in comparison with the weed dry weight under un–weeded plot. The different parameters were statistically analyzed using PROC GLM procedure of SAS version 9.2. The significance of the treatment effect was determined by the *F*–test. The significance of the difference between means of two treatments was tested using least significant difference (LSD) at 5% probability level.

RESULTS AND DISCUSSION

Tillage

The data presented in Table 1 indicated that seed yield of toria and root attributes significantly influenced ($P<0.05$) by tillage. It was noticed that MT had 44.8% higher seed yield followed by CT (26.0%) over NT. The higher yield was mainly due to minimum soil loss by erosion, sufficient soil moisture on root zone, which favoured the growth and development of plants with lowered weed growth. This was earlier corroborated by Saha *et al*. (2010). The experimental plots were severely infested by broadleaved weeds, viz. *Ageratum conyzoids, Galinsoga parviflora, Boreria hispida, Cromolina odorata, Commelina banghalensis*; grassy weed flora, viz. *Cynodon dactylon, Paspalum scrobeculatum, Digiteria singuanalis;* and sedge flora, viz. *Cyperus rotundus*. The NT plots had more number of weeds resulted competition for available resources at the site over the CT and MT. The root was 39.1% shorter and 36.8% lighter with NT and 12.0% shorter and 20.4% lighter under MT over the CT. However, MT and CT were statistically comparable. SOC was improved by 6% with NT, whereas, MT and CT registered reduction of 1.3 and 5.3%, respectively (Fig 1). The improvement of SOC in NT might be due to least interference to soil and retention of crop residues available at surface, reduced the biting action of raindrop. But, NT was close to MT as it maintained its original status (Reddy *et al*. 2004).

Sowing window

The results depicted that seed yield significantly influenced by sowing window (Fig 2a; $P<0.05$). Seed yield was 47.6% and 16.9% higher at crop sown on 15 October, than the crop sown on 1 and 30 October, respectively. The

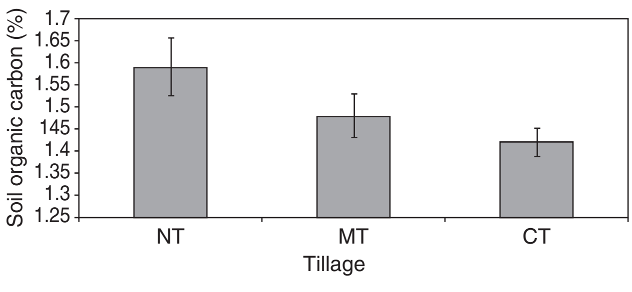

Fig 1 SOC (%) as influenced by tillage in toria (± standard deviation from the mean)

Table 1 Effect of tillage on root character and yield of toria (during 2009–2011)

Tillage	Root length (cm)	Root dry weight (g/plant)	Seed yield (kg/ ha)
No tillage	26.50±2.81[b]	5.37±0.75[b]	780.33± 12.50[c]
Minimum tillage	38.30±3.48[ab]	6.77±0.75[ab]	1130.00± 55.67[a]
Conventional tillage	43.50±3.16[a]	8.50±0.66[a]	983.33± 25.17[b]
LSD (*P*=0.05)	8.73	1.91	87.71

LSD: least significant difference; ± standard deviation from the mean; same letters in same column are not significant and different letters are statistically difference according to LSD (0.05).

lower yield on 1 October might be due to prevalence of excess moisture, this hampered the germination and emergence resulted to lower yield. Correspondingly, late sown crop experienced terminal drought during siliqua formation stages. Additionally, late sown toria faced a rapid fall in temperature, which initiated flower induction before attaining critical plant canopy; finally lead to lower seed yield (Aziz *et al*. 2011). In contrary to these, Islam and Choudhury (2002) and Bhuiyan *et al.* (2008) revealed that the early sown crop might have attributed to excessive vegetative growth over the reproductive growth of the crop, but they also reported that the late sown after 4 November considerably reduces the crop yield.

Sowing method and plant geometry

Results showed in Fig 2b affirmed that change in method of sowing considerably increase the seed yield (*P*<0.05). Line sown toria obtained 22.1% higher seed yield over broadcasting. Whereas, planting geometry with 30 × 15 cm recorded 33% higher seed yield followed by 30 × 10 cm (29%) and 45 × 15 cm (22.3%) than the crop sown at 45 × 20 cm (Fig 2c). Line sown crop received adequate nutrients, light, space and water, which helped the plants for better growth and development. This resulted higher accumulation of dry matter for producing better yield attributes. Whereas, broadcasting of seeds increased the competition among plants for available resources. The previous findings also supported that planting geometry of 30 × 15 cm required for better growth and development (Bhuiyan *et al.* 2008). Extra space in between rows helped the weeds to emerge and offer more competition with plants for various resources available at above and below ground surface. Subsequently, optimum planting geometry offer reduction in weed density, which reduced the crop–weed competition that eventually contributed to higher crop yield (Choudhary *et al.* 2014b). Higher plant density might have resulted in the competition for sunlight between the plants. The above facts are in the agreement with the earlier findings (Weber *et al.* 2003; Johnson and Hanson 2003; Singh and Dhingra 2004; Choudhary *et al.* 2014a). Row spacing of 30 cm produced significantly higher seed, stover,

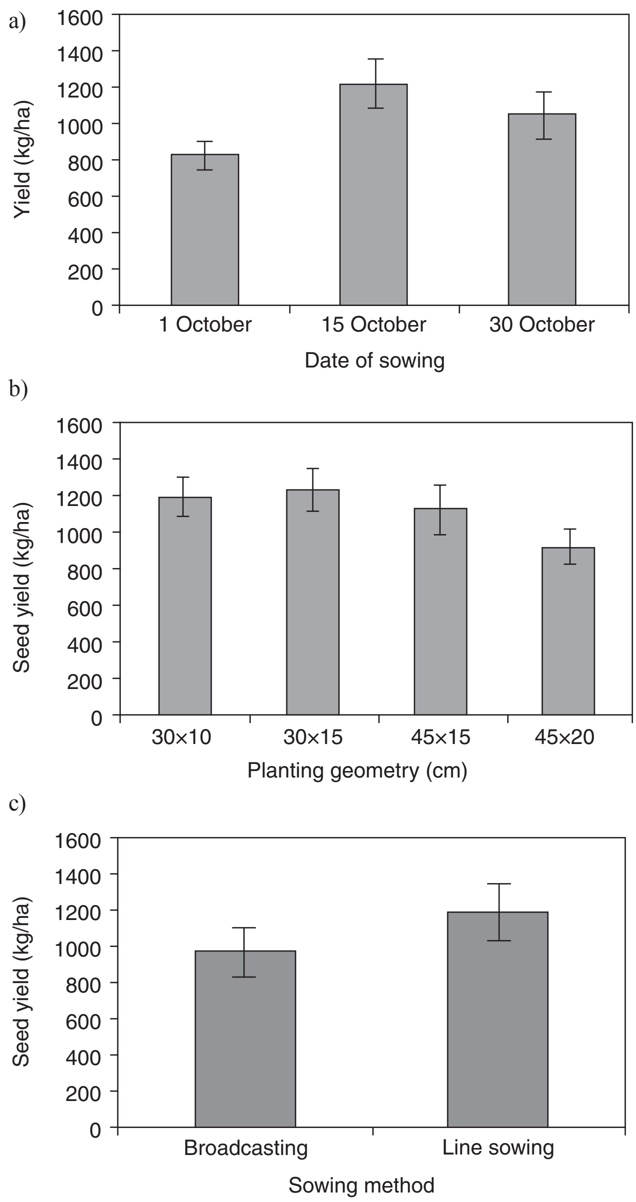

Fig 2 Seed yield of toria during 2008–2010 was influenced by a) sowing window (LSD=62.77); b) method of sowing (LSD= 200.9) and c) planting geometry (LSD= 78.3)

biological and oil yield, and net return over to 45 cm spacing (Charak *et al*. 2006).

Nitrogen

The seed yield of toria was 47% higher with application of 75 kg N/ha followed by 100 kg N/ha (39%) over the without N. But, it was well evident from Table 2 that crop yield declined beyond 75 kg N/ha. However, N uptake was higher with 100 kg N/ha followed by 75 kg N/ha and the lower N uptake was measured in without N. The nitrogen use efficiency (NUE) was 82.7% higher with 50 kg N/ha followed by 75 kg N/ha (70.2%) over without N. Agronomic efficiency was highest with 100 kg N/ha followed by 75 and 50 kg N/ha. The yield performance of toria was higher on N at 75 kg/ha. The said quantity of N was sufficient to

Table 2 Yield, N uptake, N use efficiency and agronomic efficiency as influenced by different doses of nitrogen in toria (during 2009–2011)

Nitrogen (kg/ha)	Seed yield (kg/ha)	N uptake (kg/ha)	N use efficiency	Agronomic efficiency (seed/kg N applied)
0	830.00±140.00[c]	32.13±3.81[d]		
50	980.00±125.00[b]	41.37±3.05[c]	0.827	3.00
75	1220.00±155.68[a]	52.63±3.01[b]	0.702	7.80
100	1153.33±130.55[a]	68.30±4.90[a]	0.683	6.47
LSD (P=0.05)	79.45	8.68		

develop optimum branches and accumulate sufficient dry matter for formation of sufficient numbers of siliqua (data not presented). Higher rate of N enhanced the vegetative growth and accumulate dry matter but partitioning of dry matter was improper led to flower dropping and small pods. However, considerable decrease in seed yield was observed with successive decrease of N from 75 kg/ha. The findings are in conformity with the work of Premi and Kumar (2004) and Singh and Agarwal (2004).

Phosphorus

The results depicted in Table 3 showed that application of 50 kg P/ha increased the seed yield by 61.5% followed by 75 kg P/ha (58.4%) over without phosphorus. It was also noticed that application of 25 kg P/ha improved the seed yield by 21.2%. This confirm that toria was responsive to P as it required for early establishment, root development, formation of more number of branches and siliqua/plant (Premi and Kumar 2004; Singh and Agarwal 2004). The availability of P in the experimental site was low because of high rainfall of 2450 mm/annum thus, most of the soluble salts were leached and resulted soil became acidic which ultimately restrict the availability of P. The maximum P uptake was noticed with 75 kg P/ha followed by 50 kg P/ha, but, the lowest P uptake was noticed in without applied P (Table 3). Contrarily, the P use efficiency (PUE) was 41.9% higher with 25 kg P/ha followed by 50 kg P/ha and lowest with 75 kg P/ha. It was noticed that PUE was higher with lower levels of P and decreased consequently with increased application rate. Similar finding was also reported by Ramanjaneyulu *et al.* (2010).

Table 3 Yield, phosphorus uptake and phosphorus use efficiency as influenced by different doses of phosphorus in toria (during 2009–2011)

Phosphorus (kg/ha)	Seed yield (kg/ha)	P uptake (kg/ha)	P use efficiency
0	753.33±85.17[c]	6.20±0.80[d]	
25	913.33±102.12[b]	10.47±1.12[c]	0.419
50	1216.67±135.41[a]	14.20±1.77[b]	0.284
75	1193.33±128.42[a]	18.60±1.91[a]	0.248
LSD (P=0.05)	62.12	3.39	

Water management

Table 4 showed that irrigation frequency significantly (P<0.05) influenced the seed yield. Toria had 40.5% higher seed yield when irrigated twice at 30 and 60 DAS followed by single irrigation at 30 DAS (21.4%) over no irrigation. It was estimated that toria requires 235.3–327.5 mm water at the prevailing conditions. At 30 DAS crop come to branching and irrigation at this stage contribute to more branches. Similarly, irrigation at 60 DAS helped in formation of more number of flowers resulted higher seed yield. The higher yield in irrigated plots, improve the dry matter production and distribution in different plant parts and also maintain the leaf turgor resulted to higher photosynthesis and contributed to higher yield (Choudhary *et al.* 2012). The water use efficiency (WUE) did not vary significantly but, was highest with irrigation at 30 DAS (3.78 kg/ha/mm).

Weed management

The experimental field was infested with broad leaved, grasses and sedge (as described earlier), twice hand weeding at 25 and 50 DAS increased the seed yield by 52.6% followed by single weeding at 25 DAS (18.4%) over no hand weeding (Table 5). In contrary to these, the lowest weed dry weight at harvest was obtained with twice hand weeding followed by one hand weeding. The weed control efficiency (WCE) was registered to the tune of 55.7% with twice hand weeding followed by 33.5% with one hand weeding than the un–weeded plots. Toria as poor competitor to weeds during early stage might be due to slow growing nature. But, once crop attain optimum canopy it can compete with weeds. Similar finding was also reported by Kumar and Nepalia (2002) and Chauhan *et al.* (2005). Two hand weeding caused effective and timely control of weeds and keep the crop free from weed competition. The

Table 4 Effect of water management on yield and water use efficiency of toria (during 2009–2011).

Irrigation	Effective rainfall (mm)	Soil moisture contribution (mm)§	Total water use (mm)†	Seed yield (kg/ha)	Water use efficiency (kg/ha/mm)
Without irrigation	219.7	15.6	235.3	873.3±130.6[c]	3.71±0.13[a]
One irrigation at 30 DAS	219.7	10.5	280.2	1060.0±155.7[b]	3.78±0.20[a]
Two irrigation at 30 and 60 DAS	219.7	7.8	327.5	1226.7±410.4[a]	3.74±0.13[a]
LSD (P=0.05)				119.24	NS

NS: Non significant; §: the difference of soil moisture content from beginning to final; †: includes effective rainfall, soil moisture contribution and irrigation water applied.

Table 5 Effect of weed management on yield and weed dynamics of toria (during 2009–2011)

Weed management	Seed yield (kg/ha)	Weed dry weight (g/m²)	Weed control efficiency (%)
No weeding	780.0±90.0[c]	8.1±0.28[a] (64.7)	
One weeding at 25 DAS	923.3±115.1[b]	6.6±0.23[b] (43.0)	33.5
Two weeding at 25 and 50 DAS	1190.0± 125.0[a]	5.4±0.37[c] (28.6)	55.7
LSD (*P*=0.05)	89.09	0.76	

Figures in parenthesis are original values.

similar findings were corroborated by Singh and Agarwal (2004) and Roshdy *et al*. (2008).

As per the findings of the present experiments we confer that the suitable site specific agronomic practices are recommended to obtain maximum toria seed yield. Growers and extension functionaries are advocated as per the convenience or resource available at site to obtain maximum seed yield of toria after harvesting rainy season crop. Sowing of toria with minimum tillage in line during 15 October with a planting geometry of 30 × 15 cm along with 75 kg N and 50 kg P/ha is good to harvest better crop. Similarly, as per the availability of irrigation water, growers may irrigate their crop twice at 30 and 60 DAS but, under limited water at least one irrigation may be followed at 30 DAS and twice hand weeding at 25 and 50 DAS to obtain higher seed yield. The said practices may be followed in similar agro–climatic condition elsewhere to obtain higher seed yield of toria.

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