Indian Journal of Agricultural Sciences **82** (8): 686–91, August 2012

Relationship between growth and yield of toria (*Brassica rapa* var *napus*) with thermal indices under residue management and sowing practices in hill ecosystem of north-eastern India

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Received: 24 June 2011; Revised accepted: 15 February 2012

ABSTRACT

The interdependence of growth and yield of toria [*Brassica rapa* (L) Thell. emend. Metzger var *napus* L.; syn *B. campestris* L. ssp *oleifera* (Metzger) Sinsk. var toria] with thermal indices under various residue management treatments was evaluated under hilly agro-ecosystem of Meghalaya. Field experiments were conducted in toria crop during 2006–08 with two types of tillage practices (conventional and conservation tillage), three dates of sowing (early, mid and late October) and four residue management treatments, viz. Control (no residue);M_0, maize stalk cover (MSC); M_1, MSC + locally available weed, *Ambrossia* sp. @ 10 tonnes/ha; M_2 and MSC + farmyard manure (FYM) @ 10 tonnes/ha; M_3. The thermal indices, viz. accumulated growing degree days (GDD), heat-use efficiency (HUE) were computed for seed yield as well as total dry matter of toria and simultaneously regression equations between yield parameters and thermal indices were developed. Irrespective of tillage treatments, accumulated GDD was 22% higher in early sowing as compared to late sowing and contributed to lowest toria seed yield in early-sown condition. The highest HUE of 9.77 and 8.44 kg/ha/°C day for dry matter and 1.45 and 1.52 kg/ha/°C day for seed yield was recorded in M_2 under conventional and conservation tillage practices, respectively. Significant linear relationships were observed between seed yield and total dry matter with heat-use efficiency. Therefore, mid and late October sowing with MSC + *Ambrossia* sp. @ 10 tonnes/ha; M_2 was most efficient for getting better toria seed yield under hilly terrain condition of north- east India.

Key words: Hill agriculture, Residue management, Thermal indices, Toria

The growth and productivity of crops depend on the elements of the physical environment in a particular ecosystem. Temperature is an important factor that affects crop growth. Yield of crop can be taken as a product of rate of biomass accumulation (solar radiation dependent) and the growth duration (ambient air temperature dependent). Efficiency of conversion of heat energy into dry matter depends on genetic factors, sowing time and crop type (Sikder 2009). The most imminent change is the increase in the atmospheric temperature due to increased levels of greenhouse gases. The global mean annual temperatures at the end of 20th century were almost 0.7°C above than those recorded at the end of the 19th century and is likely to increase further by 1.8 to 6.4°C by 2100 AD (Kaur and Rajni 2010). The important effect of high temperature is accelerated physiological development, resulting in hastened maturation and reduced yield. Agroclimatic models based on thermal indices such as growing degree days (GDD), heat-use efficiency (HUE) and other related parameters can be useful for prediction of crop growth and yield. Attempts have been made by many workers to predict phenology and growth and yield (Hundal *et al.* 2003a, b) of crops using thermal indices.

In hilly eco-system of north-eastern parts of India, mostly rainfed agriculture is practised, because of which the production level is much lower as compared to other parts of the country. During winter (*rabi*) season, crop production without any soil moisture conservation practice is virtually simply impossible due to inadequate residual soil moisture. Under such situation, residue management might be the right proposition for providing favourable soil moisture for crop growth, as incorporation of organic matter either in the form of crop residue, organic manure or amendment has significant effect on soil aggregation and soil moisture retention capacity (Abrol and Sangar 2006). Toria [*Brassica rapa* L. Thell. emend. Metzger var *napus* L.; syn *B. campestris* L. ssp *oleifera* (Metzger) Sinsk. var toria] is the most commonly cultivated

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crop during winter (*rabi*) season in this region with the exception of winter vegetables. It is used both as source of edible oil as well as leafy vegetable for which its popularity has increased tremendously in this region. It is mostly grown during October to February. Management of mustard production components are closely linked with climatic and edaphic factors and therefore, proper sowing time has to be standardized based on the agro-climatic models. Therefore, this study has been conducted to evaluate the interdependence of growth and yield of toria with thermal indices under various residue management treatments so as to recommend the best management practices under hilly agro-ecosystem.

MATERIALS AND METHODS

The field experiment was conducted during three consecutive years (2006–08) at the research farm of the Indian Council of Agricultural Research Complex for North Eastern Hill Region, Umiam (25° 41´N, 91° 63´E, 980 m above sea level), Meghalaya. The area is representative of the mild tropical hill zone and the climate is per-humid. The average maximum temperature, minimum temperature and rainfall during winter (*rabi*) season are 23.2 °C, 8.6 °C and 121 mm, respectively at Umiam. The soil of the study area is acidic in nature classified under *Typic Hapludalf*. The treatments consisted two tillage systems (conventional and conservation tillage), three sowing dates (early, mid and late October) and four residue management practices [Control (no residue);M_0, maize stalk cover (MSC);M_1, MSC + *Ambrossia* sp. @ 10 tonnes/ha;M_2 and MSC + farmyard manure (FYM) @ 10 tonnes/ha; M_3].

Conventional tillage practice is mostly the traditional one, i e the plot was power tilled (4 passes), whereas in conservation tillage, the field remains untouched i e without any tillage operation and *Glyphosate* was applied for weed control. Moreover, the crop stubbles and weeds were kept on the soil surface for soil moisture conservation. Maize was sown in June with recommended agronomic practices as *kharif* crop. Biomass of a local weed *Ambrosia* spp and FYM were applied as per treatment between rows of standing maize stalk at 20 days before its harvest in September. Immediately after harvest of maize, its stalk was spread all over the field just above the applied *Ambrossia* and kept as such till sowing of toria. Toria was sown in October between maize rows by pushing maize stalk both the sides. In case of conservation tillage, toria seeds were sown by dibbling method. The maize stalks were put back between toria rows and kept till harvest of toria. This way *Ambrosia* spp and maize stalk act as 'double mulch' particularly for toria.

The toria var. toria (TS 36) was sown in October as per treatments at a row spacing of 45 cm at the seed rate of 5 kg/ha following the recommended package of practices. The cop received 40 kg N/ha in the form of urea, 60 kg P/ha as single super phosphate (SSP) and 40 kg K/ha as muriate of potash (MOP). Whole plant samples were collected periodically and dry matter (DM) accumulation was recorded for all the treatments. The crop was harvested at maturity and simultaneously the seed yield was recorded.

Growing degree-days (GDD) were accumulated from the date of sowing to harvesting of crop to give accumulated GDD (°C days) using base temperature of 5°C. Heat-use efficiency (HUE) was computed to compare the relative performance of mustard under various treatments using the formula (Sastry *et al.* 1985):

$$\text{HUE} = \frac{\text{Seed or total dry matter yield (kg/ha)}}{\text{Growing degree-days (°C days)}}$$

Seed yield and total dry matter of toria were correlated with thermal units by regression analysis. Experimental data obtained from the study were statistically analyzed in split-plot design using standard analysis of variance (Gomez and Gomez 1984). The significance of the treatments effects was determined by t-test. To determine the significance of the difference between the means of the treatments least significant difference (LSD) was computed at 5% probability level.

RESULTS AND DISCUSSION

Crop yield

In general, all the residue management practices recorded good seed yield of toria which was several times higher than control (M_0), where only negligible yield was observed (Table 1 and 2). The treatment MSC + *Ambrosia* spp @ 10 tonnes/ha (M_2) recorded highest yield (2 353 kg/ha) which is almost 8-fold higher than the toria yield under control plot (389 kg/ha). Similar trend was observed in case of dry matter accumulation. The low yield obtained in control might be because of very low soil moisture available, particularly during flowering and pod development stage, thus, could not support toria growth, branching and pod formation. The crop performance under conventional tillage was good as compared to that under conservation tillage for the initial two years. However, the performance of conservation tillage is much superior to conventional tillage during the third year. In fact, conversion period of conservation tillage is reported to be 3–5 years in this region. This could be due to constant addition of organic matter through residue and weed biomass influencing soil physical, chemical and biological properties owing to the favourable effect of crop biomass and manure on the soil physical and biological properties and physiological functions of toria (Ghosh *et al.* 2010). Results depicted that seed as well as total dry matter yield was highest for sowing done in mid October, followed by late October and early October under both the tillage practices.

Thermal indices

Accumulated growing degree-days (GDD), total dry matter accumulated at physiological maturity, seed yield and

Table 1 Thermal indices and yield of toria in various treatments under conventional tillage during study periods (2006–08)

Crop year	Sowing time	Residue management treatments	AGDD* (°C day)	Total dry matter (kg/ha)	Seed yield (kg/ha)	Dry matter HUE† (kg/ ha/°C day)	Seed yield HUE (kg/ ha/°C day)
2006	S_1- early October	M_0	2038.1	2271	334	1.11	0.16
2007			2062.2	2363	315	1.15	0.15
2008			2082.2	2412	371	1.16	0.18
		Mean ± SE	2060.8 ± 32.3	2349^a ± 36.5	340^a ± 11.2	1.14 ± 0.02	0.16 ± 0.01
		M_1	2038.1	10104	1780	5.94	0.87
			2062.2	9588	1545	5.62	0.75
			2082.2	11194	1876	5.86	0.9
		Mean ± SE	2060.8 ± 32.3	10295^b ± 44.1	1734^b ±46.0	5.81 ± 0.12	0.84 ± 0.07
		M_2	2038.1	12511	2134	7.12	1.05
			2062.2	11600	2080	7.56	1.01
			2082.2	13294	2353	7.35	1.13
		Mean ± SE	2060.8 ± 32.3	12468^c ± 30.6	2189^c ± 42.8	7.34 ± 0.18	1.06 ± 0.05
		M_3	2038.1	10853	1890	6.31	0.93
			2062.2	9565	1767	6.43	0.86
			2082.2	11982	2055	6.42	0.99
		Mean ± SE	2060.8 ± 32.3	10800^b ± 39.2	1904^b ± 29.8	6.39 ± 0.08	0.93 ± 0.04
	S_2- mid October	M_0	1852.5	2808	413	1.52	0.22
			1857.1	2977	397	1.6	0.21
			1875.1	3032	405	1.4	0.22
		Mean ± SE	1861.6 ± 12.5	2939^a ± 48.3	405^a ± 8.2	1.51 ± 0.12	0.22 ± 0.01
		M_1	1852.5	13300	2250	8.26	1.21
			1857.1	13819	2109	8.52	1.14
			1875.1	12587	2092	7.25	1.12
		Mean ± SE	1861.6 ± 12.5	13235^c ± 34.7	2150^c ± 33.9	8.01 ± 0.19	1.16 ± 0.05
		M_2	1852.5	14726	2548	9.35	1.38
			1857.1	13858	2336	9.43	1.26
			1875.1	15520	2704	9.37	1.44
		Mean ± SE	1861.6 ± 12.5	14701^c ± 50.2	2529^d ± 58.2	9.38 ± 0.06	1.36 ± 0.13
		M_3	1852.5	11763	2185	8.02	1.18
			1857.1	10273	1903	7.69	1.02
			1875.1	11058	2162	7.49	1.15
		Mean ± SE	1861.6 ± 12.5	11031^{bc} ± 26.4	2083^c ± 46.0	7.73 ± 0.23	1.12 ± 0.09
	S_3- late October	M_0	1666.5	2462	362	1.48	0.22
			1681.3	2475	330	1.47	0.19
			1702.4	2509	386	1.47	0.23
		Mean ± SE	1683.4 ± 32.7	2482^a ± 22.7	359^a ± 15.4	1.47 ± 0.02	0.21 ± 0.02
		M_1	1666.5	11784	1880	7.67	1.13
			1681.3	11655	1674	7.47	1
			1702.4	12681	1951	7.45	1.15
		Mean ± SE	1683.4 ± 32.7	12040^c ± 29.0	1835^b ± 37.6	7.53 ± 0.14	1.09 ± 0.04
		M_2	1666.5	13476	2276	9.29	1.37
			1681.3	13085	2190	9.77	1.3
			1702.4	14422	2468	9.42	1.45
		Mean ± SE	1683.4 ± 32.7	13661^d ± 32.4	2311^d ± 34.5	9.49 ± 0.22	1.37 ± 0.07
		M_3	1666.5	10552	1993	8.13	1.2
			1681.3	9965	1875	8.36	1.12
			1702.4	11559	2086	7.96	1.23
		Mean ± SE	1683.4 ± 32.7	10692^b ± 48.9	1985^{bc} ± 40.3	8.15 ± 0.28	1.18 ± 0.05
		LSD (P=0.05)	73.4	1232.8	376.2	1.19	0.27

*AGDD: Aggregated growing degree days, † HUE: heat-use efficiency Treatment details: M_0; Control (no residue), M_1; maize stalk cover (MSC), M_2;MSC + *Ambrossia* sp. @ 10 tonnes/ha and M_3; MSC + farmyard manure (FYM) @ 10 tonnes/ha. Values in each column sharing same letter are not significantly different (P < 0.05)

Table 2 Thermal indices and yield of toria in various treatments under conservation tillage during study periods (2006–08)

Crop year	Sowing time	Residue management treatments	AGDD* (°C day)	Total dry matter (kg/ha)	Seed yield (kg/ha)	Dry matter HUE† (kg/ha/°C day)	Seed yield HUE (kg/ha/°C day)
2006	S_1- early October	M_0	2038.1	1666	245	0.82	0.12
2007			2062.2	2002	308	0.97	0.15
2008			2082.2	2573	415	1.24	0.2
		Mean ± SE	2060.8 ± 32.3	2080[a] ± 76.4	323[a] ± 47.9	1.01 ± 0.12	0.16 ± 0.03
		M_1	2038.1	7684	1130	3.77	0.55
			2062.2	8976	1455	4.3	0.71
			2082.2	11006	2070	5.77	0.99
		Mean ± SE	2060.8 ± 32.3	9222[b] ± 66.2	1552[b] ± 60.2	4.61 ± 0.98	0.75 ± 0.16
		M_2	2038.1	10592	2006	5.21	0.98
			2062.2	13665	2278	6.63	1.1
			2082.2	13903	2437	6.44	1.17
		Mean ± SE	2060.8 ± 32.3	12720[c d] ± 59.0	2240[c] ± 54.0	6.09 ± 0.77	1.08 ± 0.10
		M_3	2038.1	10842	1694	5.32	0.83
			2062.2	10916	1922	5.78	0.93
			2082.2	12365	2096	5.94	1.01
		Mean ± SE	2060.8 ± 32.3	11374[d] ± 43.3	1904[d] ± 73.5	5.68 ± 0.36	0.92 ± 0.07
	S_2- mid October	M_0	1852.5	2128	313	1.15	0.17
			1857.1	2567	395	1.38	0.21
			1875.1	3001	484	1.6	0.26
		Mean ± SE	1861.6 ± 12.5	2565 [a] ± 68.3	397 [a] ± 25.8	1.38 ± 0.23	0.21 ± 0.04
		M_1	1852.5	9037	1329	4.88	0.72
			1857.1	10053	1648	5.41	0.89
			1875.1	12789	2205	6.82	1.18
		Mean ± SE	1861.6 ± 12.5	10626 [d] ± 79.1	1727 [b] ± 58.4	5.70 ± 1.06	0.93 ± 0.18
		M_2	1852.5	12038	2280	6.5	1.23
			1857.1	14547	2428	7.84	1.31
			1875.1	15073	2741	8.04	1.46
		Mean ± SE	1861.6 ± 12.5	13886 [c] ± 65.2	2483 [c] ± 43.7	7.46 ± 1.39	1.33 ± 0.11
		M_3	1852.5	12116	1893	6.54	1.02
			1857.1	13494	2015	6.73	1.09
			1875.1	13181	2234	7.03	1.19
		Mean ± SE	1861.6 ± 12.5	12930 [c] ± 44.0	2047[c d] ± 55.5	6.77 ± 0.31	1.07 ± 0.03
	S_3- late October	M_0	1666.5	1850	272	1.11	0.16
			1681.3	2303	354	1.37	0.21
			1702.4	2726	440	1.6	0.26
		Mean ± SE	1683.4 ± 32.7	1726 [a] ± 91.2	355 [a] ± 73.2	1.36 ± 0.19	0.21 ± 0.04
		M_1	1666.5	8622	1268	5.17	0.76
			1681.3	9455	1550	5.62	0.92
			1702.4	10569	2167	7.38	1.27
		Mean ± SE	1683.4 ± 32.7	9549 [b] ± 88.8	1662 [b] ± 80.9	6.06 ± 0.76	0.98 ± 0.18
		M_2	1666.5	10320	2144	6.79	1.29
			1681.3	13197	2365	8.44	1.41
			1702.4	14244	2590	8.37	1.52
		Mean ± SE	1683.4 ± 32.7	12587 [c] ± 74.5	2366 [c] ± 48.6	7.87 ± 0.62	1.07 ± 0.13
		M_3	1666.5	9398	1781	6.84	1.07
			1681.3	10307	1985	7.32	1.18
			1702.4	12821	2173	7.53	1.28
		Mean ± SE	1683.4 ± 32.7	10842 [d] ± 81.6	1980 [d] ± 66.6	7.23 ± 0.44	1.18 ± 0.11
		LSD (*P*=0.05)	73.4	1493.2	241.9	0.97	0.22

*AGDD: Aggregated growing degree days, † HUE: heat-use efficiency Treatment details: M_0; Control (no residue), M_1; maize stalk cover (MSC), M_2; MSC + *Ambrossia* sp. @ 10 tonnes/ha and M_3; MSC + farmyard manure (FYM) @ 10 tonnes/ha. Values in each column sharing same letter are not significantly different ($P < 0.05$)

HUE are given in Tables 1 and 2. In general, accumulated GDD was higher in early sowing as compared to late sowing, irrespective of tillage treatments. The GDD varied in between 2038.1 and 2082.2 °C day, 1852.5 and 1875.1 °C day and 1666.5 to 1702.4 °C day for crop sown in early October, mid October and late October, respectively. The simultaneous drop in accumulated GDD was because of inclusion of cool months of winter. The HUE was generally more under mid October and late October sown crop than early October sown crop. The highest HUE of 9.77 and 8.44 kg/ha/°C day for dry matter and 1.45 and 1.52 kg/ha/°C day for seed yield was recorded in M_2 under conventional and conservation tillage practices, respectively. Among the three different sowing times, mid and late October were most efficient in terms of HUE because of low temperature, which decreased the accumulated GDD. Similar results for HUE of toria crop were also reported by Kaur and Hundal (2006) under Punjab condition.

Relationship between thermal indices and toria yield

Relationship between HUE vs. seed yield and HUE vs. total dry matter were developed separately through regression analysis. It was observed that there exists a significant (at 5% level) linear relationship between HUE and seed yield (Fig 1) under both the tillage practices. Similar significant (at 5% level) linear relationship was found between HUE and total dry matter (Fig 2). This result substantiates the findings of Kaur *et al.* (2004). These relationships can be used to estimate growth and yield of toria using daily meteorological information on temperature, photoperiod or sunshine duration within the crop season enabling in forecasting the toria yield under hilly ecosystem.

Thus, the study suggested that mid and late October sowing with residue management practice of retaining biomass of previous maize crop and applying the most abundant weed/grass *Ambrossia* sp. @ 10 tonnes/ha as soil cover under M_2 treatment improved toria productivity. Moreover, the regression equations can be applied to estimate growth and yield of toria using daily meteorological data, particularly temperature and photoperiod within crop season. Therefore, conservation tillage with appropriate resource-conserving techniques, can improve the farmer's income, put in use on-farm resources and ultimately ensure food security in marginal areas in the hilly ecosystem.

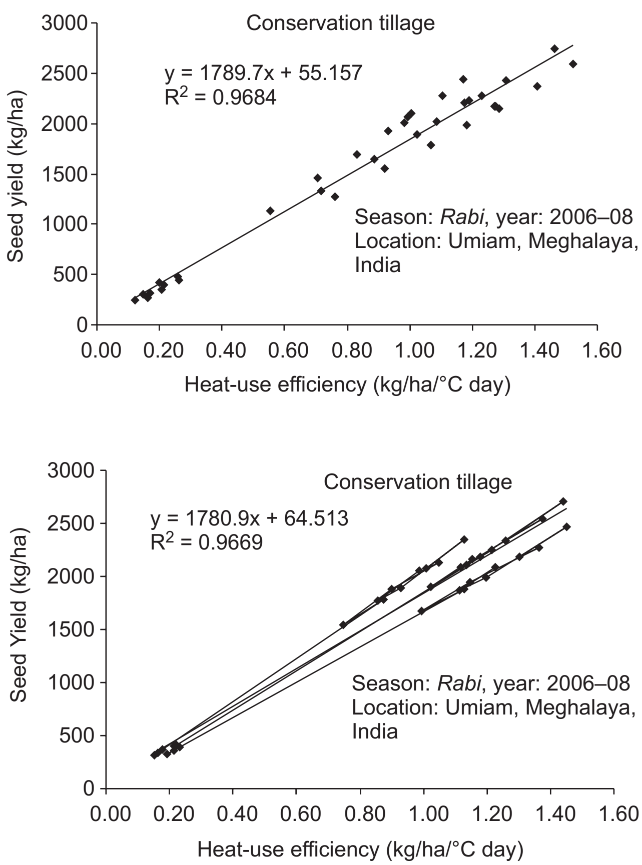

Fig 1 Relationship between heat-use efficiency and seed yield of mustard under conservation and conventional tillage practices

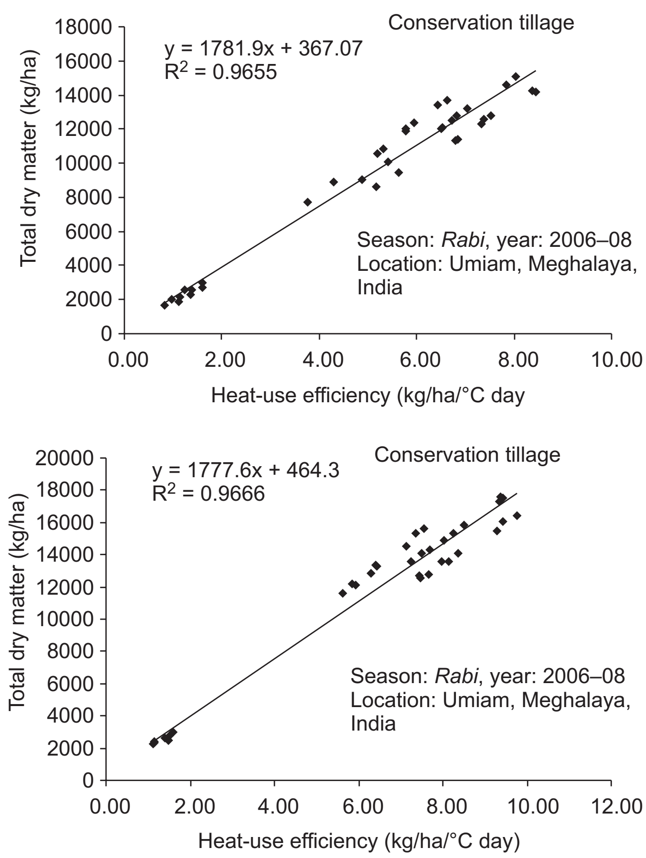

Fig 2 Relationship between heat-use efficiency and total dry matter of mustard under conservation and conventional tillage practices

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