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Growth dynamics of Indian mustard (*Brassica juncea* L.) *cv*. Pusa Tarak as influenced by irrigation levels and row spacings

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Abstract

Field experiment was conducted to study the effect of irrigation levels and row spacings on total above ground dry matter accumulation, dry matter partitioning, crop growth rate and relative growth rate of Indian mustard [*Brassica juncea* (L.) Czern & Coss.] cultivar Pusa Tarak during two consecutive *Rabi* seasons of 2012-13 and 2013-14 at Jawaharlal Nehru Krishi Vishwa Vidayalaya, College of Agriculture, Tikamgarh (Madhya Pradesh), India. The experiment was laid out in split-plot design with three replications consisted three irrigation levels *viz*., control (I_0:no post sowing irrigation), one irrigation at 40 DAS (I_1) and two irrigations at 40, and 75 DAS (I_2) as main plot treatments and three row spacings *viz*., 20 cm (S_1), 30 cm (S_2), and 40 cm (S_3) as sub-plot treatments. The results revealed that irrespective of treatment variations, dry matter accumulation in leaves and stem started slowly at early growth stage (30 DAS) and increased thereafter, and was partitioned maximum in the reproductive parts at harvest. The maximum dry matter accumulation was observed with two irrigations (at 40 DAS and 75 DAS) with 40 cm row spacing. The crop growth rate (CGR) was significantly affected by irrigation and row spacing. However, relative growth rate (RGR) was significantly influenced only by irrigation levels. Higher accumulation of dry matter in mustard ultimately elevated the seed yield as confirmed by relationship study between seed yield and dry matter accumulation.

Key words: *Brassica juncea, dry matter partitioning, Indian mustard, irrigation level, row spacing*

Introduction

India is the third largest oil seed producing country in the world. Rapeseed and mustard group of crops account for 21 % of the area and 23 % of the seed production of total oilseeds in the country (Isssa and Sharma, 2007). The area, production and productivity of rapeseed-mustard in India was 6.90 million ha, 8.18 million tonnes and 1185 kg ha^{-1}, respectively till 2009-10 (Anonymous, 2012). Indian mustard accounted for about 75–80% of the total area under these crops in the country during 2009–10. However, productivity of mustard is quite low in the country against the world average of 1400 kg ha^{-1}. Of the several reasons, non-availability of adequate irrigation is the most important one. Owing to hardy and capacity to thrive well under poor soil moisture, mustard is seldom irrigated and is generally raised as a rainfed crop in India. However, the crop responds well to irrigation and it is a vital factor for proper growth and development of this crop in dry season. Plant growth and development are the result of many physiological processes which are influenced by soil moisture (Begum and Paul, 1993). Yield of Indian mustard is greatly influenced by irrigation and better results both in terms of biometric components and seed yield can be achieved by the application of optimum irrigation. The economic yield is greatly determined by the production of total dry matter and its partition to the reproductive organ (Singh and Yadav, 1989). Amongst the possible ways of promoting dry matter accumulation, optimum irrigation levels and row spacing are important (Johason and Hanson, 2003). Establishment of optimum plant

Table 1: Total above ground dry matter accumulation (g plant^{-1}) of Indian mustard plants at different growth intervals (DAS) as affected by irrigation levels and row spacings

Treatments	Days after sowing (DAS)				
	30	45	60	75	90
Irrigation levels					
I_0	0.90	2.44	3.80	5.80	5.48
I_1	0.91	2.85	4.87	7.70	8.18
I_2	0.99	2.88	5.01	7.81	8.90
S.Em±	0.03	0.15	0.21	0.09	0.26
CD at 5%	NS	NS	0.65	0.27	0.80
Row spacings					
S_1	0.80	2.35	3.25	6.67	6.20
S_2	0.93	2.78	5.11	7.27	7.45
S_3	1.07	3.05	5.32	7.38	8.92
S.Em±	0.04	0.11	0.28	0.14	0.28
CD at 5%	0.15	0.36	0.89	0.44	0.88
Irrigation levels x Row spacings					
I_0 S_1	0.76	2.00	2.52	5.15	3.99
I_0 S_2	0.90	2.54	4.54	5.99	5.67
I_0 S_3	1.03	2.78	4.33	6.27	6.79
I_1 S_1	0.78	2.51	3.60	7.43	7.04
I_1 S_2	0.93	2.84	5.28	7.90	8.05
I_1 S_3	1.03	3.20	5.34	7.90	9.45
I_2 S_1	0.86	2.53	3.62	7.43	7.55
I_2 S_2	0.97	2.95	5.52	7.94	8.63
I_2 S_3	1.14	3.16	6.29	7.96	10.51
S.Em±	0.07	0.15	0.25	0.11	0.27
CD at 5%	0.23	0.47	0.79	0.35	0.85

I_0 = No irrigation, I_1 = Single irrigation at 40 DAS, I_2 = Two irrigations at 40 and 75 DAS
S_1 = 20 cm row spacing, S_2 = 30 cm row spacing, S_3 = 40 cm row spacing

population by maintaining proper row spacing is one of the important factors to secure a better translocation of photosynthates, which render better yield of crop (Alam, 2004). Optimum row spacings are necessary for interception of sunlight to each strata of leaves. This will enhance the rate of photosynthesis and consequently, the dry matter production which can ultimately increase the crop yield. Taking the above mentioned points in view, the present study was undertaken to investigate the impact of optimum irrigation levels and suitable row spacing on growth dynamics of Indian mustard variety Pusa Tarak.

Materials and Methods

The field experiment was conducted at Research Farm, Jawaharlal Nehru Krishi Vishwa Vidayalaya, College of Agriculture, Tikamgarh (24° 43' N latitude, 78° 49' E longitude at an altitude of 358 m above mean sea level), Madhya Pradesh, India during two consecutive *Rabi* seasons of 2012-13 and 2013-14. The experimental site is of sub-tropical climate characterized by hot dry summers, and cool dry winter and lies in the Bundelkhand Zone (Agro-climatic Zone-VIII). The soil of experimental field

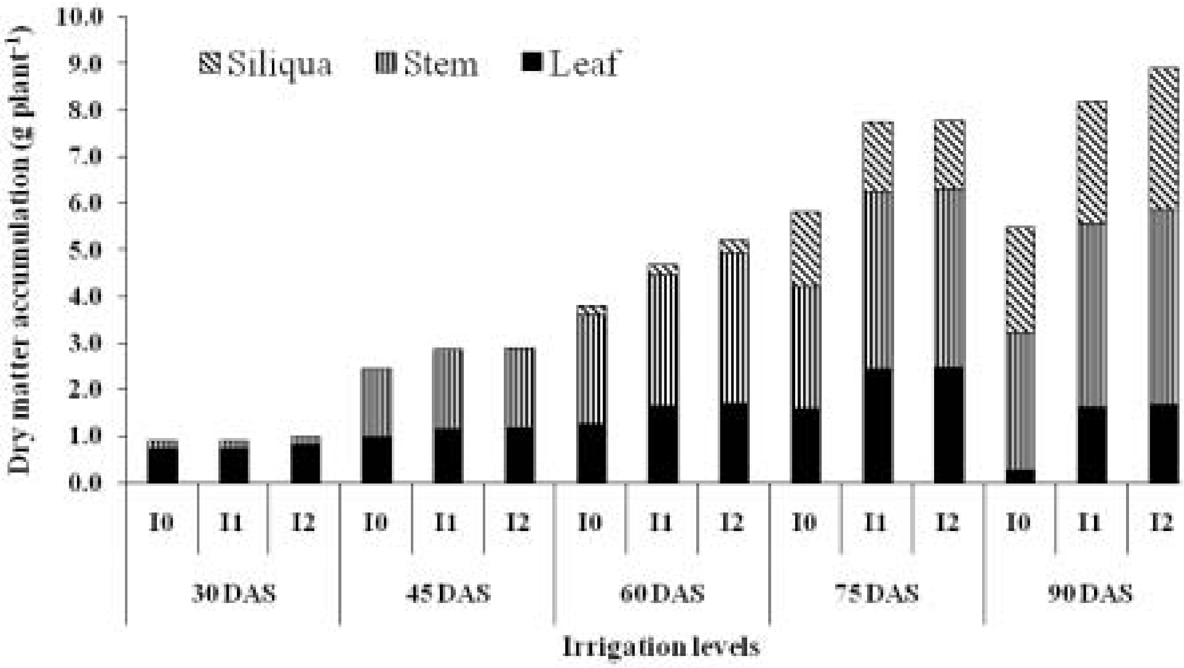

Fig. 1: Dry matter accumulation in different parts of mustard plant at different growth intervals as affected by different irrigation levels

was medium to deep black and clayey loam in texture having pH 7.0, EC 0.12 dS m^{-1}, organic carbon 0.5%, available N 260.5 kg ha^{-1}, available P_2O_5 25.9 kg ha^{-1}, and available K_2O 255.1 kg ha^{-1}, respectively. The average annual rainfall of this region is about 1000 mm, which is mostly received between June to September, and a little rainfall (90 mm) is also obtained during October to May. The average temperature ranges between 4.5 °C to 45 °C. The weather parameters during experiment were recorded at the Meteorological Observatory located at Research Farm, College of Agriculture, Tikamgarh, MP, India.

The experiment was conducted in split-plot design with three replications and comprised of three irrigation levels *viz*., control (I_0:no post sowing irrigation), one irrigation at 40 DAS (I_1), and two irrigations at 40, and 75 DAS (I_2) as main plot treatments and three row spacings *viz*., 20 cm (S_1), 30 cm (S_2), and 40 cm (S_3) as sub-plot treatments. The sowing of mustard crop was done on 01 November of 2012 and 2013 in lines, 20, 30 and 40 cm apart (as per treatments) drawn by *kudali* using a seed rate of 5 Kg ha^{-1}. The full recommended doses of nitrogen (20 kg N ha^{-1}), phosphorus (40 kg P_2O_5 ha^{-1}), and potassium (20 kg K_2O ha^{-1}) were applied as basal through urea, SSP and murate of potash, respectively just below the soil. All other agronomic and plant protection measures were applied as per recommendations. Ten plants from each treatment were sampled periodically at 30, 45, 60, 75, and 90 DAS and at maturity to record data on total above ground dry matter accumulation and its partitioning into leaves, stem, and siliquae (g $plant^{-1}$). Seed yield (g $plant^{-1}$) was recorded from the ten plants sample collected at the time of harvest. Crop growth rate (CGR) and Relative growth rate (RGR) were calculated following the formulae given by Brown (1984), and Radford (1967), respectively. The results of both the years were more or less similar and hence two years data were pooled and analyzed statistically to draw suitable inference as per standard ANOVA technique described by Gomez and Gomez (1984).

Results and Discussion

***Dry matter accumulation and its partitioning*:** The data pertaining to total above ground dry matter accumulation (g $plant^{-1}$) as influenced by

Table 2: Crop growth rate (g m^{-2} d^{-1}) of Indian mustard *cv*. Pusa Tarak plants as affected by irrigation levels and row spacing

Treatments	Days after sowing (DAS)			
	30-45	45-60	60-75	75-90
Irrigation levels				
I_0	2.38	1.89	3.44	-0.82
I_1	3.03	2.69	4.82	0.36
I_2	2.96	3.22	5.01	1.38
S.Em±	0.24	0.23	0.27	0.09
CD at 5%	NS	0.73	0.85	0.30
Row spacings				
S_1	3.44	2.00	2.60	-1.05
S_2	2.72	3.08	4.44	0.26
S_3	2.20	2.72	6.24	1.71
S.Em±	0.20	0.21	0.23	0.06
CD at 5%	0.64	0.67	0.74	0.21
Irrigation levels x Row spacings				
I_0 S_1	2.76	1.16	0.83	-2.57
I_0 S_2	2.42	2.52	3.39	-0.47
I_0 S_3	1.95	1.97	6.11	0.57
I_1 S_1	3.84	1.97	3.48	-0.87
I_1 S_2	2.82	3.17	4.65	0.23
I_1 S_3	2.41	2.64	6.33	1.73
I_2 S_1	3.71	2.86	3.48	0.28
I_2 S_2	2.92	3.36	5.29	1.03
I_2 S_3	2.24	3.74	6.28	2.84
S.Em±	0.19	0.20	0.29	0.11
CD at 5%	0.61	0.65	0.92	0.37

I_0 = No irrigation, I_1 = Single irrigation at 40 DAS, I_2 = Two irrigations at 40 and 75 DAS
S_1 = 20 cm row spacing, S_2 = 30 cm row spacing, S_3 = 40 cm row spacing

irrigation levels, and row spacings are given in Table 1. Irrespective of treatments, accumulation of total above dry matter was very slow at initial stage (30 DAS) and thus no responses were observed due to treatment variables. Total dry matter accumulation did not differ significantly among irrigation levels at 30, and 45 DAS. Thereafter, application of one irrigation at 40 DAS (I_1), two irrigations at 40, and 75 DAS (I_2), were at par with each other, which produced significantly more total above dry matter at 60, 75 and 90 DAS than no irrigation application (I_0). Similar results were also reported by Giri (2001) and Thakur (2013). Among row spacings, 30 and 40 cm row spacings resulted into more total above dry matter accumulation at 30, 45, 60, and 75 DAS. However, at 90 DAS, wider row spacing of 40 cm produced significantly more total above dry matter followed by 30 cm and narrow row spacing of 20 cm. Singh and Singh (1984) and Chauhan *et al*. (1993) also suggested wider row spacing of 40 cm for greater dry matter production in rapeseed. Interactional effects indicated that treatment combination, I_1 x S_3 produced significantly highest dry matter at 90 DAS as compared to other treatment combinations (Table 1). Lowest dry matter accumulation at all stages was recorded from

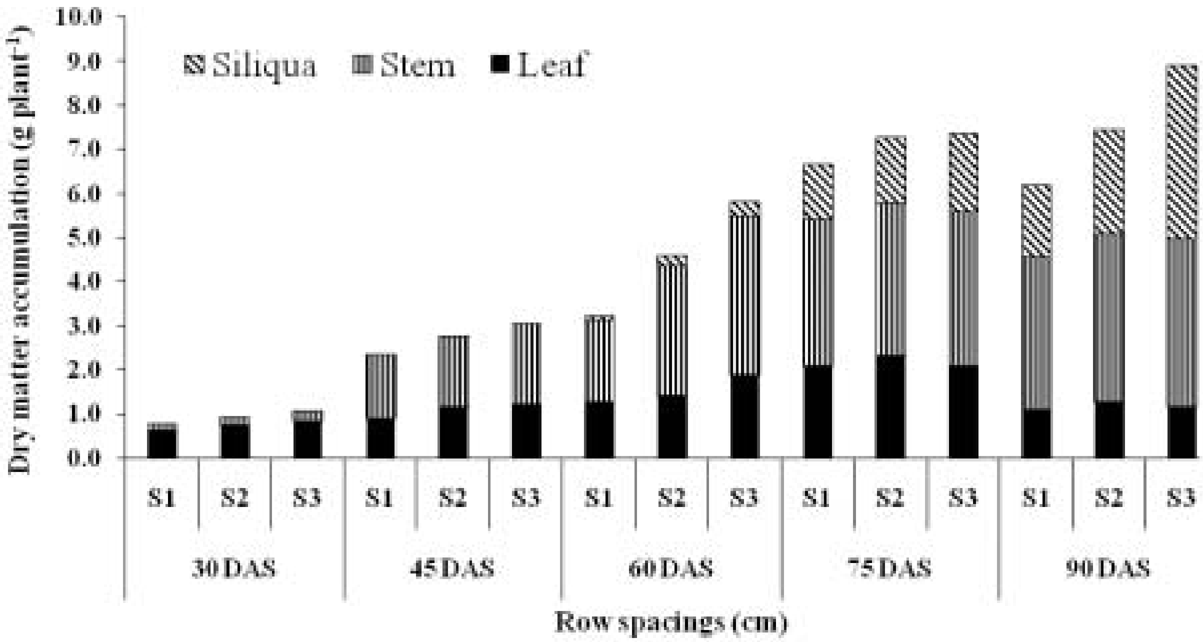

Fig. 2: Dry matter accumulation in different parts of mustard plant at different growth intervals as affected by different row spacings

the plants with no irrigation (I_0) and under maximum intra competition of plant for an area (S_1).

Irrespective of treatments, dry matter partitioning into different plant parts was very slow in the early growth stage of growth (30 DAS) and increased rapidly towards maturity (Figs. 1 and 2.). Leaves accounted for up to 33.7, 30.6, 15.8; stem 61.6, 48.3, 49.2, and siliquae 4.7, 21.1, 35.0 % of above ground total dry matter accumulation at 60, 75, and 90 DAS, respectively. Dry matter partitioning into stem increased up to harvest, whereas partitioning into leaves was found lower at 90 DAS, which could be attributed due to the leaf senescence and mobilization of metabolites from leaves to siliquae. The partitioning of dry matter towards siliquae started at 60 DAS and reached maximum at 90 DAS. The similar trend of dry matter partitioning in rapeseed and mustard were also reported by Siddique (1999), Alam (2004) and Thakur (2013).

Irrigation levels did not influence the dry matter distribution towards leaves and stem at 30 and 45 DAS. Thereafter, application of one irrigation at 40 DAS (I_1) and two irrigations, 40 and 75 DAS (I_2), were at par with each other, which gave maximum dry matter partitioning into leaves, stem and siliquae over no irrigation application (I_0) at 60, 75, and 90 DAS (Fig. 1). Among row spacings, wider row spacing of 40 cm resulted into maximum partitioning of dry matter into siliquae at 90 DAS over other row spacings. On the other hand, row spacings were failed to influence the dry matter partitioning into different parts of mustard plant at other all growth intervals, (Fig. 2). These results corroborate with the findings of Lodhi *et al*. (1979) and Thakur (2013).

***Crop growth rate (CGR) and relative growth rate (RGR)*:** In general, the CGR was slow at early stage, and maximum between 60 and 75 DAS which declined up to harvest (Table 2). Irrigation levels significantly influenced CGR from 45 to 90 DAS. Significantly higher CGR values were obtained with application of two irrigations (I_2) at all growth intervals followed by application of single irrigation (I_1), and no irrigation application (I_0). However, CGR did not differ significantly between irrigation treatments I_1 and I_2. The plants which were under water stress (I_0) gave significantly lowest CGR values.

Table 3: Relative growth rate (g g^{-1} d^{-1}) of Indian mustard *cv*. Pusa Tarak plants as affected by irrigation levels and row spacing

Treatments	Days after sowing (DAS)			
	30-45	45-60	60-75	75-90
Irrigation levels				
I_0	0.030	0.011	0.012	-0.002
I_1	0.034	0.015	0.014	0.001
I_2	0.031	0.014	0.016	0.003
S.Em±	0.001	0.001	0.001	0.001
CD at 5%	NS	0.003	0.003	0.002
Row spacings				
S_1	0.032	0.012	0.014	-0.003
S_2	0.033	0.014	0.013	0.001
S_3	0.030	0.015	0.015	0.005
S.Em±	0.001	0.001	0.001	0.001
CD at 5%	NS	NS	NS	NS
Irrigation levels x Row spacings				
I_0 S_1	0.030	0.008	0.014	-0.007
I_0 S_2	0.033	0.012	0.011	-0.002
I_0 S_3	0.028	0.012	0.013	0.002
I_1 S_1	0.034	0.013	0.016	-0.002
I_1 S_2	0.034	0.017	0.013	0.000
I_1 S_3	0.034	0.016	0.013	0.005
I_2 S_1	0.032	0.013	0.016	0.000
I_2 S_2	0.033	0.013	0.015	0.002
I_2 S_3	0.029	0.016	0.016	0.008
S.Em±	0.002	0.002	0.001	0.002
CD at 5%	NS	0.006	0.003	0.007

I_0 = No irrigation, I_1 = One irrigation at 40 DAS, I_2 = Two irrigations at 40 and 75 DAS
S_1 = 20 cm row spacing, S_2 = 30 cm row spacing, S_3 = 40 cm row spacing

At initial stages (30 to 60 DAS), the CGR was more with narrow row spacing (S_1) and intermediate row spacing (S_2), whereas at the later stage (60 to 90 DAS), CGR was recorded maximum with wider row spacing of 40 cm. This might be due to decreased efficiency of leaves at higher population densities (Siddiqui, 1999; Alam, 2004; Thakur, 2013). Inter-actional effect showed that combination of wider row spacing of 40 cm with I_0, I_1, and I_2 showed higher CGR as compared to other combination of narrow and intermediate row spacing with different irrigation levels. Similar trend was also reported by Khader and Bhargava (1985) and Alam (2004).

Irrespective of treatments, the RGR values were found greater at early growth stage (30-45 DAS) then declined towards maturity (Table 3). The initial stage of a plant is important from RGR point of view as greater dry mater supports plants to have early growth coverage for initial dry matter production. Application of single irrigation at 40 DAS (I_1) and application of two irrigations at 40 and 75 DAS (I_2) exhibited significantly greater RGR over no irrigation (I_0) at all growth intervals. An optimum moisture regime is very important for the balanced metabolic activities of the plants, which in turn might have resulted in increased growth of the plants similar to

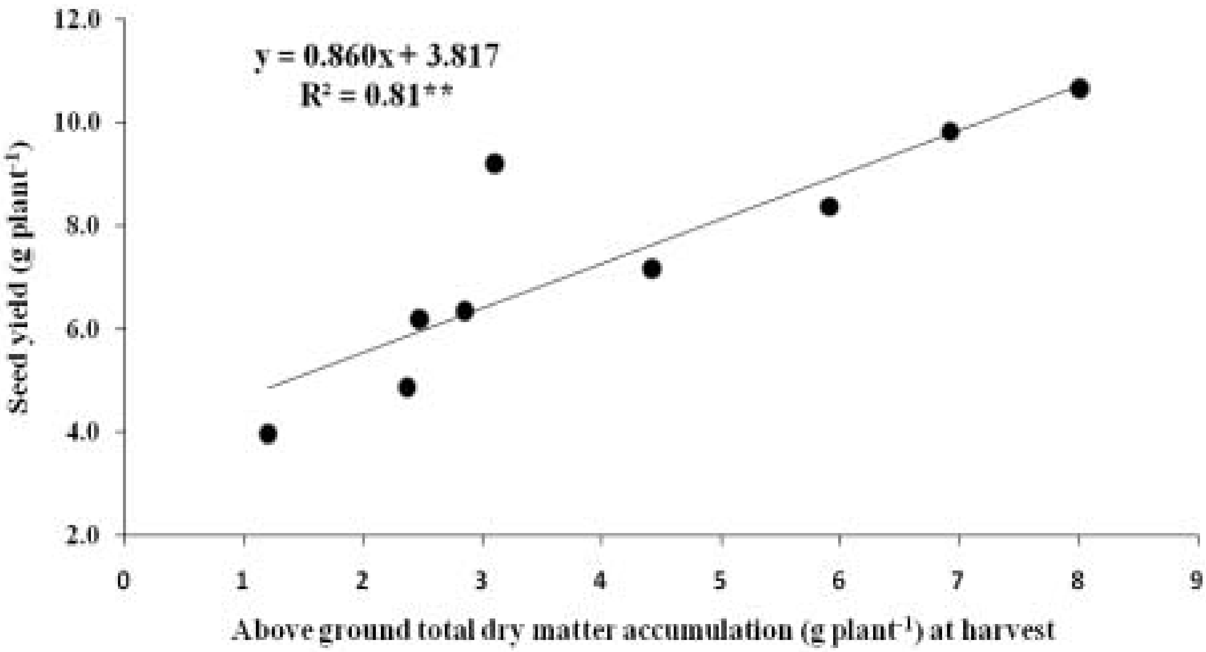

Fig. 3: Relationship between above ground dry matter and seed yield of mustard *cv.* Pusa tarak

the findings of Prasad and Ehsanullah (1988). At initial stages RGR was the maximum with intermediate spacing (30 cm) and thereafter maximum RGR was attained by widest spacing (40 cm). However the row spacing did not exert any significant effect on the RGR of mustard at any growth stages (Table 3). Siddiqui (1999) and Roshid (1998) observed similar results in rapeseed and sesame, respectively. The combined effect of wider row spacing of 40 cm with I_0, I_1, and I_2 showed higher RGR as compared to other combination of narrow and intermediate row spacing with different irrigation levels at all growth intervals except at 30-45 DAS.

***Relationship between seed yield and total above ground dry matter*:** The relationship between seed yield and total above ground dry matter was strongly positive, linear and significant (R = 0.81**). The slope for seed yield and total above ground dry matter indicated that an increment of 1.0 g total above ground dry matter promotes 0.86 g seed yield (Fig. 3). Chowdhury *et al*. (1999) and Thakur (2013) also reported similar relationship in rapeseed and mustard.

Conclusion

From the results of two-year field investigation during *Rabi* 2012-13 and 2013-14, it was highlighted that Indian mustard *cv*. Pusa Tarak may be cultivated both at 40 cm and 30 cm row spacing along with two irrigation, one at 40 DAS and another at 75 DAS for optimum dry matter production and higher yield.

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