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Land configurations in surface drip irrigation for enhancing productivity, profitability and water-use efficiency of Indian mustard (*Brassica juncea*) under semi-arid conditions

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ABSTRACT

The aim of the experiment was to maximize water-use efficiency and resultant crop productivity through surface drip irrigation under modified land techniques in arid- and semi-arid conditions of India. To address these issues, field study was undertaken on Indian mustard [*Brassica juncea* (L.) Czern. & Coss.] with surface drip irrigation under various land configuration techniques to enhance water-use efficiency, crop productivity and profitability. Results of the study revealed that flat sowing drip irrigation system in 60/30 and 30/60 cm land configuration resulted in highest seed yield (141 to 161 %), oil productivity (139 to 150%) and water-use efficiency of mustard seed (141 to 162 %) over flat 90/60cm land configuration. Better growth and yield attributes of Indian mustard were also recorded in land configuration of flat sowing in 60/30 and 30/60cm. Maximum net return of ₹ 102×10^3 obtained at 30/60cm flat sowing followed by flat sowing at 60/30cm land configuration over other land configurations under drip irrigation. Likely, sowing of mustard at 30/60cm followed by 60/30cm flat land configuration with surface drip irrigation produced highest root biomass (79 to 94%), root length density (75to 86%), root volume density (135 to 169%) and root mass density (65 to 125%) over 90/60cm flat land configuration. Among ridge and furrow land configuration, 30/60cm ridge and 60/30cm furrow sowing found better in producing highest seed and oil yields, better economics over 90/60cm furrow.

Key words: Drip irrigation**,** Moisture content, Photosynthetic rate, Root biomass, Soil moisture tension, Yield

India contributes about 6-7% of the world oilseeds production (Economic Times 2018). Drip system is most suited to water scarce regions of semi-arid and arid, where low water consuming, and high value crops can be grown. Indian mustard [*Brassica juncea* (L.) Czern & Coss.] is an important oilseed crop, mainly grown under arid- and semi-arid conditions of India, occupying about 6.0 m ha with a production of about 7.98 m t and productivity of 1324.0 kg/ha (Anonymous 2016). Large acreage of Indian mustard under water stressed ecologies mainly due to the better adaptation under variable agro-climatic conditions *vis a vis* respond very well to judicious irrigation water management. Drip irrigation is promising technology under water stressed conditions to maximize the water use efficiency in mustard. Any effort made to reduce the length of lateral required per unit area of the field will result in reduction of the system cost. Rectangular, square, equilateral and hexagonal arrangements were tested, and it was concluded that for all the crops, paired row planting reduced the cost and water use by 50% (Aujila *et al.* 2005). India is facing shortage of edible oils and enhancing their productivity is imperative for self-reliance. Indian mustard is the largest contributor of domestic oil production in India, still huge gap exists in present and potential productivity (Rathore *et al.* 2014). The decreasing availability of water to agriculture sector has become a serious limitation in many areas. The increasing demand of water by non-agricultural sector will further reduce the share of water for crop production. Hence, drip irrigation with suitable land configuration is the potent water saving technologies to counter the deficit without missing the production targets adoption. In present scenario, the limited available water is applied in the field though check basin, where water-use efficiency hardly exceeds 40%. One-time application of irrigation water resulted in excess water supply at one stage and moisture stress at other growth stages which affects growth, reduced photosynthesis, primary and secondary branches, main shoot length, number of seeds/ siliqua, length of siliqua and seed yield of Indian mustard (Rathore *et al.* 2018). Adaptive advantages of mustard to water stress also reported by Wright *et al.* (1996); Rathore *et al.* (2018), but the response of Indian mustard under land configurations under drip system are not adequate. Keeping

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these points in view the field experiment was conducted with the objective to enhance mustard productivity with efficient use of available irrigation water in drip irrigation system under different land configuration system.

MATERIALS AND METHODS

Field study was conducted at ICAR-Directorate of Rapeseed-Mustard Research, Bharatpur research farm during 2012-13 and 2013-14. Experiment was formulated with seven land configurations under flat and raised bed were assessed in a randomised block design with three replications. Each individual plot comprised flat (30cm), 30/60 ridge, 60/30 furrow, 90/60 furrow, flat 60/30, 30/60 flat and 90/60 flat patterns. The drip laterals were kept as per the land configuration for ensuring maximum uniformity in irrigation water distribution. The soil of experiment site was loamy clay and saline-sodic with pH 8.5-9.5 and EC varied from 0.5-0.9 dS/m. The soils were poor in organic carbon (2.1–2.4 g/kg), $KMnO_4$ oxidizable N (130–150 kg/ha), medium in 0.5N $NaHCO_3$, extractable P_2O_5 (18.2–21.5 kg/ha) and 1.0N NH_4OAC exchangeable K_2O (200–270 kg/ha). The bulk density and infiltration rate of the soil was 1.50 Mg/m^3 and 3.8-4.5 mm/hr, respectively. The total dissolved solids (TDS) and salt TDS was 1200 and 750ppm, respectively.The range of maximum and minimum temperatures were 17–33.8 and 3.4–20.1^{o}C and compared to 2013-14, lower minimum temperature was recorded during 2012-13 during January, however contrary trend was observed in maximum temperature except for October month. Pan evaporation was less than 2.0 mm per day during November to February 2012-13 and higher evaporation was recorded during October and March month. Relative humidity was remained higher from November to February, except during October and March month during both the years. High relative humidity (Max and Min) during grand growth period during January and February also created favourable conditions for fungal infection in crops of white rust and stem rot.

The mustard cv. Rohini was sown in the first fortnight of October during both years. The seeds were sown at 30 × 10 cm spacing at a depth of 5 cm with a seed drill, with seed rate of 5.0 kg/ha. Before sowing, the seed was treated with carbendazim 2.0 g/kg seed and metalaxyl (Apron 35 SD) 6.0 g/kg seed against deadly diseases of stem rot and white rust, respectively.Thinning was done at 15-20 days after sowing (DAS) to maintain plant-to-plant distance. Phosphorus (40 kg/ha) as single super phosphate and potassium (40 kg/ha) as muriate of potash were applied as basal at the time of land preparation. Half dose of N and full dose of P and K were applied as basal, whereas the remaining N in the form of urea was applied through fertigation in micro irrigation systems.

Irrigation water was applied in such a manner to ensure better water availability to the crop as per its requirement, therefore irrigation water was scheduled though drip irrigation system as per the water requirement of the crop. FAO Irrigation Water Management Training Manual No. 3 (Brouwer and Heibloem 1986) was taken as reference to quantify the volume of water. Water productivity is calculated by using mustard yield as numerator and consumptive use (CU) of water as denominator,

Water productivity (WP) = kg seed/ha-mm CU

Fertigation of nitrogen was done through urea fertilizers with the help of ventuary attached with the micro irrigation system in the main line. The required pressure for fertigation through ventuary was 1.5 kg/cm^2. Soil sampling was done from 0–30, 30–60, 60–90 and 90–120 cm soil depth for soil moisture studies at periodical intervals of 30 days from sowing to harvesting with the help of screw auger. The soil samples were immediately kept in aluminium boxes and covered with lid to avoid moisture loss. The soil samples were dried at 105^{0}C constant weight was obtained. Moisture content in depth was worked out, the total soil moisture depleted (SMD) from root zone (0–90 cm) was estimated by summing up the depletion from each layer. Soil moisture content by weight basis with the help of gravimetric method was done regularly from different soil depth and soil moisture tension was monitored and recorded with tensiometers at different depth. The observation of pan evaporation was recorded from agromet station placed near to the experiment.

The data on yield and yield attributes were statistically analysed using Fisher's analysis of variance technique and the treatments means were compared by Duncan's Multiple Range (DMR) test at level of 0.05 probabilities. The standard analysis of variance (ANOVA) test was performed using SPSS 17.0 statistical software to compare the treatment means for each year separately.

RESULTS AND DISCUSSION

Growth and yield attributes: The plant height was not affected by land configuration, however biomass accumulation and main shoot length of mustard varied significantly ($P \leq 0.05$), maximum biomass (53.8g/plant) and main shoot length (87.1cm) were recorded significantly in 30/60 flat land configuration over other treatments (Table 1). Primary and secondary branches did not influence significantly by land configuration techniques. Leaf area index at different growth stages also obtained highest under 30/60 and 60/30 flat land configurations over 90/60 flat and other ridge and furrow treatments (Fig 1). Photosynthetic rate was recorded at various growth stages and found highest in flat 60/30cm land configuration at 30, 50, 70 and 90 DAS, which was slightly followed by flat 30/60 land configuration over ridge and furrow sowing (Fig 2). Among yield attributes, main shoot length (MSL), which is considered a stable trait, was influenced by land configuration, highest MSL was in flat sowing at 30/60 and 30/60 land configuration. Siliqua on primary, secondary branches, and main stem were also determined by land configurations and 30/60, 60/30cm flat sowing was observed with maximum number, and similar was the trend with total siliqua/plant. Seeds per siliqua were also varied in flat, raised bed and

Table 1 Effect of land configuration and drip irrigation on growth and yield attributes of Indian mustard (Pooled mean of 2 years)

Treatment	Plant height (cm)	Biomass (g/ plant)	Main shoot length (cm)	Primary branches	Secondary branches	Siliqua on			Total siliqua / plant	Seeds per siliqua			Siliqua length (cm)	1000 seed weight (g)
						MS	PB	SB		MS	PB	SB		
Flat (30cm)	193^{a}	40.9^{ab}	81.7^{bc}	4.6^{ab}	5.5^{a}	57.3^{c}	122^{b}	86^{a}	268^{b}	11.9^{b}	12.1^{ab}	11.8^{b}	3.8^{bc}	5.7^{d}
30/60 ridge	189^{a}	42.2^{b}	82.6^{bc}	4.5^{ab}	7.0^{a}	37.1^{a}	119^{b}	98^{ab}	255^{b}	12.3^{b}	11.5^{ab}	11.8^{b}	3.7^{bc}	5.6^{cd}
60/30 furrow	195^{a}	49.2^{c}	78.3^{bc}	4.2^{a}	7.5^{a}	44.8^{ab}	127^{b}	114^{b}	283^{b}	10.3^{a}	11.3^{ab}	11.3^{b}	4.1^{c}	5.4^{c}
90/60 furrow	188^{a}	40.0^{ab}	72.0^{ab}	4.7^{ab}	7.3^{a}	41.5^{ab}	123^{b}	94^{ab}	259^{b}	10.4^{a}	13.0^{b}	10.2^{a}	4.0^{bc}	4.9^{b}
Flat 60/30	184^{a}	48.5^{c}	75.3^{b}	5.6^{b}	6.9^{a}	38.9^{a}	134^{b}	137^{c}	310^{cd}	13.2^{b}	13.2^{b}	13.4^{c}	3.4^{a}	6.1^{e}
30/60 flat	197^{a}	53.8^{c}	87.1^{c}	4.6^{ab}	7.7^{a}	49.3^{bc}	135^{b}	143^{c}	326^{d}	14.9^{c}	14.7^{c}	13.9^{c}	3.8^{bc}	6.4^{e}
90/60 flat	187^{a}	35.7^{a}	62.3^{a}	5.1^{ab}	6.9^{a}	41.2^{ab}	96^{a}	77^{a}	212^{a}	9.1^{a}	10.4^{a}	10.1^{a}	3.7^{ab}	4.6^{a}

Within column, value represents with different letter indicate significant difference ($P<0.05$); MS, main stem; PB, primary branches; SB, secondary branches

ridge system and maximum number of siliquae was in 30/60 and 60/30 flat sowing, however for siliqua length, trend was erratic. The weight of 1000 seeds are a strong indication of good seed filling and was significantly higher ($P\leq0.05$) 1000 seed weight was recorded in 30/60, 60/30 flat sowing. The higher growth and yield attributes under flat 60/30 and 30/60 land configuration were due to optimum space received by plant, and uniform and better distribution of irrigation water which may enable the plants to absorb plant nutrient efficiently. These probable reasons were also explained by Shekhawat *et al.* (2012); Rathore *et al.* (2014) for enhancing growth under optimum land configurations. Better uptake of nutrients and water resulted in higher photosynthetic rate (Fig 2) in mustard crop under land configuration 30/60 and 60/30 flat sowing might be the reason for higher growth and biomass accumulation. The favourable soil moisture and nutrient regimes promoted higher nutrients and water uptake and subsequently better growth parameters (plant height, LAI, branching and dry matter production), which also resulted, efficient partitioning, adequate translocation and accumulation of photosynthates (Hariom *et al.* 2013). However, under 90/60cm flat and furrow methods, mustard plants unable to utilize the available resources due to sparse plant population accompanied by lower soil moisture led to lower growth and yield parameters.

Root biomass, length and volume density : Root biomass was recorded at regular interval of 15 days, after 30 DAS to 90 DAS, irrespective of time of sampling at any crop stage from 30, 45,60, 75 and 90 DAS, higher root biomass was attained in 30/60 and 60/30 flat sowing. There was sharp increase in root dry matter during initial stage of 30-60 DAS. But during 75 to 90 days after sowing (DAS), increase in dry matter of roots was relatively low and it was stabilized at 90 DAS (Table 2). Root length density, root volume density and root mass density were recorded at 90 DAS, were significantly ($P\leq 0.05$) influenced by land configuration at different depth of the soil. The results revealed that every density parameter (root length density, RLD; root mass density (RMD) and root volume density (RVD) reduced with soil depth irrespective of land configuration types. However, root length density (RLD) was maximum at 0-10 cm and was decreased gradually with soil depth and least value of RLD was recorded at 20-30 cm of soil depth. Similar was the trend in root volume and root mass density. Among all land configurations, 60/30 and 30/60 flat sowing were recorded better root biomass at every crop stage and higher root length, volume and mass density (Table 3).The lower root length density at depth causes poor access to water for the roots. For this reason, rooting depth of the field crops has been of considerable interest (White *et al.* 2015). For example, soil moisture and nutrient regimes decides to greater extent on the amount and depth of the roots, since total root mass was closely correlated with the accumulation of thermal time (Barraclough and Leigh 1984). From the above findings, the land configuration 60/30 and 30/60 cm flat sowing under drip system had the greatest effect on the distribution of roots with depth (Table 3). Root volume increased with increase in

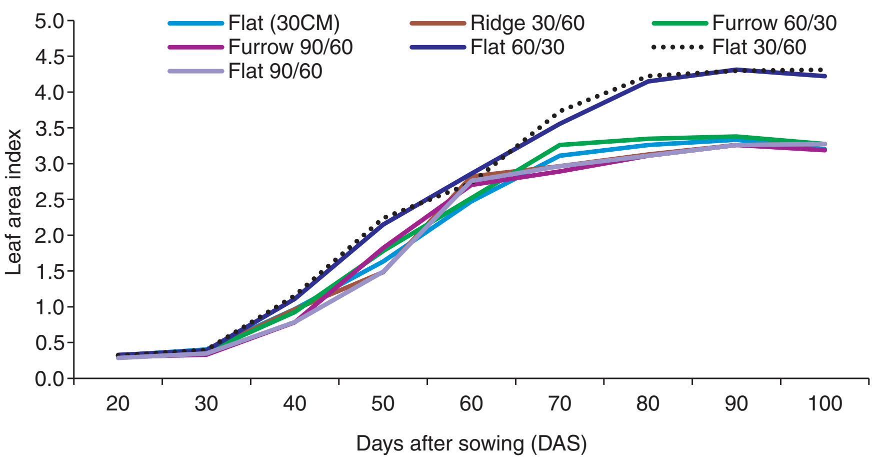

Fig 1 Leaf area index over 20-100 days after sowing of Indian mustard under different land configurations.

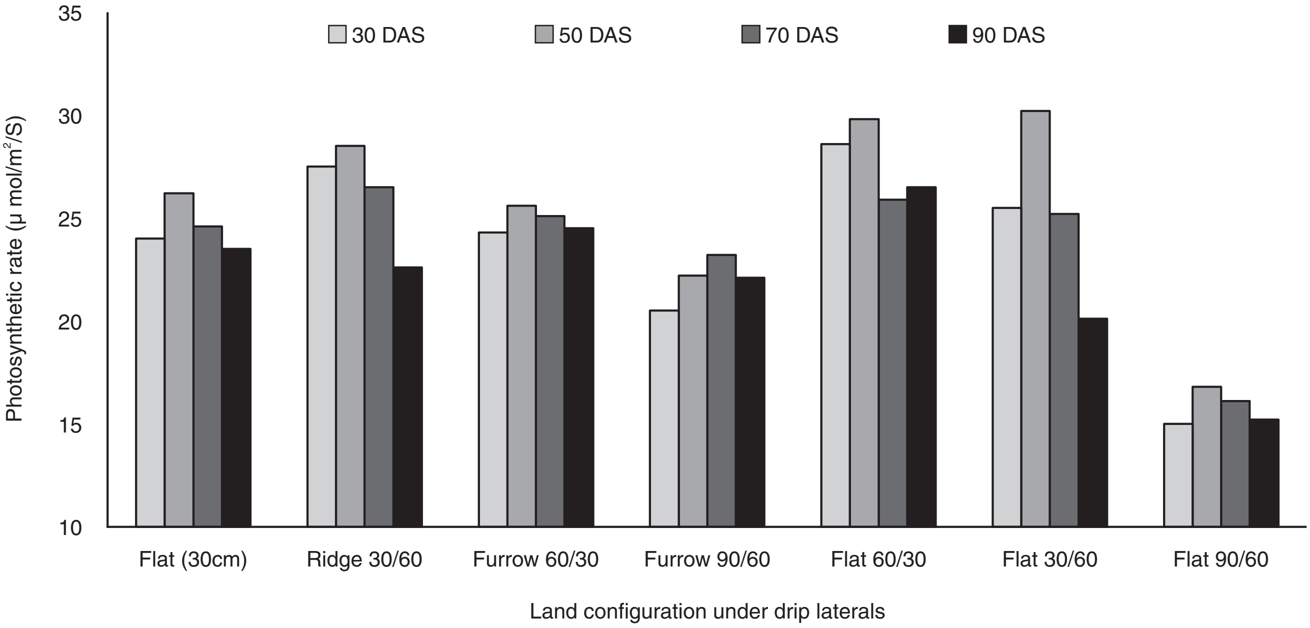

Fig 2 Photosynthetic rate of Indian mustard under different land configurations.

amount of soil moisture, probably since the crop had to transport higher water to meet the greater ET demand created by the greater leaf area, LAI, photosynthesis, biomass production (Patra *et al.* 2000) and root density and depth determines the soil water availability and the pattern of water extraction to a large extent under beds (Rajanna *et*

Table 2 Root biomass and root density of *Brassica juncea* under different land configurations (Pooled mean of 2 years)

Treatment	Root biomass (g/plant) at successive growth stages (days after sowing)					Root length density (cm/cm^3)			Root volume density ×10^{-2} (cm/cm^3)			Root mass density (mg/cm^3)		
	30	45	60	75	90	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
Flat (30CM)	12.8^{b}	41.2^{b}	75.5^{b}	125.2^{c}	135.2^{c}	1.61^{b}	0.98^{b}	0.58^{b}	2.81^{b}	1.81^{b}	0.75^{b}	4.21^{b}	2.81^{b}	0.71^{b}
Ridge 30/60	11.5^{ab}	41.5^{b}	76.5^{b}	120.5^{c}	131.5^{c}	1.62^{b}	0.92^{b}	0.54^{ab}	2.75^{b}	1.75^{b}	0.78^{b}	4.30^{b}	2.72^{b}	0.68^{ab}
Furrow 60/30	12.1^{b}	40.5^{b}	72.8^{b}	126.5^{c}	1342^{c}	1.65^{b}	0.8^{ab}	0.51^{ab}	2.68^{b}	1.78^{b}	0.75^{b}	4.21^{b}	2.61^{b}	0.69^{ab}
Furrow 90/60	10.1^{ab}	32.5^{a}	65.2^{a}	110.5^{b}	125.2^{b}	1.10^{ab}	0.70^{ab}	0.42^{a}	1.82^{a}	1.1^{a}	0.40^{a}	3.40^{a}	1.85^{ab}	0.40^{a}
Flat 60/30	13.6^{bc}	55.8^{c}	89.2^{bc}	131.5^{cd}	165.5^{d}	1.76^{bc}	1.05^{bc}	0.76^{c}	3.81^{c}	2.51^{c}	1.28^{c}	5.12^{c}	3.42^{c}	0.98^{c}
Flat 30/60	15.5^{c}	60.5^{c}	98.5^{c}	140.5^{d}	168.3^{d}	1.82^{c}	1.11^{c}	0.80^{c}	4.22^{cd}	2.72^{c}	1.30^{c}	5.92^{c}	3.58^{c}	1.12^{c}
Flat 90/60	9.2^{a}	31.2^{a}	62.1^{a}	98.6^{a}	115.1^{a}	0.98^{a}	0.6^{a}	0.38^{a}	1.62^{a}	1.01^{a}	0.35^{a}	3.10^{a}	1.62^{a}	0.31^{a}

Within column, value represents with different letter indicate significant difference ($P<0.05$)

Table 3 Moisture content at different soil profile depth (%) and its use pattern in the soil at critical growth stages of Indian mustard.

Treatment	Moisture content (% w/w)						Moisture use pattern %					
	Soil depth (cm)						Soil depth (cm)					
	0-30		30-60		60-90		0-30		30-60		60-90	
	FS	SD	FS	SD	FS	SD	FS	SD	FS	SD	FS	SD
Flat (30cm)	14.6^{ab}	15.5^{b}	15.8^{ab}	16.2^{a}	17.2^{b}	17.6^{a}	42^{ab}	40^{a}	25^{a}	24^{a}	19.2^{a}	18.6^{a}
Ridge 30/60	14.9^{b}	15.2^{ab}	15.6^{ab}	16.5^{ab}	17.1^{b}	18.2^{ab}	45^{b}	41^{a}	24^{a}	25^{a}	20.1^{a}	19.5^{a}
Furrow 60/30	15.1^{b}	15.8^{b}	15.8^{ab}	16.8^{b}	17.3^{b}	18.6^{b}	43^{ab}	44^{b}	26^{ab}	27^{b}	20.5^{ab}	20.2^{ab}
Furrow 90/60	15.8^{b}	14.8^{a}	16.3^{b}	15.8^{a}	17.1^{b}	17.8^{a}	41^{a}	42^{a}	28^{b}	26^{ab}	19.6^{a}	20.3^{ab}
Flat 60/30	13.9^{a}	15.9^{b}	14.9^{a}	16.7^{b}	16.8^{ab}	18.5^{b}	42^{ab}	43^{ab}	27^{ab}	23^{a}	21.5^{ab}	21.2^{b}
Flat 30/60	13.2^{a}	16.4^{b}	14.6^{a}	16.9^{b}	16.2^{ab}	18.4^{b}	40^{a}	42^{a}	24^{a}	24^{a}	22.0^{b}	18.9^{a}
Flat 90/60	13.1^{a}	15.2^{a}	14.8^{a}	16.1^{a}	15.6^{a}	17.8^{a}	39^{a}	41^{a}	24^{a}	23^{a}	19.1^{a}	18.8^{a}

Within column, value represents with different letter indicate significant difference ($P<0.05$); FS, Flowering stage; SD, Siliqua development

Table 4 Seed, biological yield, production efficiency and harvest index of Indian mustard under drip irrigation in different land configuration (Pooled mean of 2 years).

Treatment	Seed yield (kg/ha)	Biological yield (kg/ha)	Oil content (%)	Oil yield (kg/ha)	Production efficiency (kg/ha/day)	Harvest index	WUE seed (kg seed/ ha-mm)	WUE biomass (kg DM /ha-mm)
Flat (30cm)	2351^{bc}	8133^{bc}	42.7^{b}	992^{b}	16.4^{b}	0.29^{d}	26.1^{a}	90.4^{b}
Ridge 30/60	2290^{bc}	8810^{cd}	41.0^{a}	1001^{b}	17.2^{b}	0.29^{d}	25.4^{a}	97.9^{b}
Furrow 60/30	2227^{b}	8996^{cd}	42.6^{b}	1008^{b}	16.7^{b}	0.27^{bc}	24.7^{a}	100.0^{b}
Furrow 90/60	1495^{a}	5901^{ab}	42.4^{b}	642^{a}	10.7^{a}	0.26^{abc}	16.6^{a}	65.6^{a}
Flat 60/30	2757^{cd}	11038^{de}	42.7^{b}	1179^{b}	19.4^{b}	0.23^{a}	30.6^{bc}	122.6^{c}
Flat 30/60	2992^{d}	11672^{e}	$41.8a^{b}$	1231^{b}	20.7^{b}	0.24^{ab}	33.2^{c}	$129.^{7c}$
Flat 90/60	1146^{a}	3996^{a}	42.4^{b}	493^{a}	8.2^{a}	0.28^{d}	12.7^{a}	44.4^{a}

Within column, value represents with different letter indicate significant difference (P<0.05); WUE, Water-use efficiency; DM, Dry matter

al. 2016). This was the reason for higher seed productivity under 30/60 and 60/30 cm flat sowing. For oilseed rape (*B. campestris*), Mandal *et al.* (2006) also reported greater root volume and dry weight under favourable soil moisture regimes.

Soil moisture use pattern and water-use efficiency: Soil moisture content (SMC) by weight basis was estimated at crop critical stages for moisture stress, i.e. flowering stage and siliqua development stages at 0-30, 30-60, 60-90 cm of soil depth. Significantly not much variation was observed in SMC under surface drip irrigation oriented various land configurations at all the growth stages. Careful perusal of moisture use pattern (%) from different soil depth indicates higher soil moisture was extracted from 0-30 cm soil depth and with increase in soil depth, relatively lesser soil moisture was being used by the crop plant and at 60-90 cm of soil depth, lowest soil moisture (19–21% at flowering and 19–21 % at siliqua development stage) was used. Water-use efficiency (WUE) of mustard influenced significantly by land configuration techniques (Table 3). WUE on seed and biomass basis was estimated and found significantly higher in flat sowing at 60/30 (30.6 and 122.6 kg/ha-mm, respectively) and at 30/60 (33.2 and 129.0 kg/ha-mm, respectively) over other flat, furrow and ridge type of land configurations. Suitable land configuration in drip irrigation ensures that the water is supplied straight to the crop root zone, where the efficiency of water use is extremely high as it substantially reduces the evaporation, conveyance and distribution losses of water (Dhawan 2002; Narayanamoorthy 2009). Similarly, flat land configuration at 60/30 and 30/60cm attained highest soil moisture content at all the growth stages. This shows available limited water was efficiently utilized by the crop with land configuration of flat sowing at 60/30 and 30/60 sowing under drip irrigation system in Indian mustard.

Seed, oil productivity and economics: The most important parameters seed, biological and oil yield were significantly influenced by land configuration systems (Table 4). Land configuration at flat 30/60 was recorded significantly higher (P≤0.05) seed yield (2992 kg/ha) and biological yield of mustard (11672 kg/ha) over other land configurations but it was at par with 60/30 flat land configuration. Whereas the treatments flat 90/60 and furrow 90/60 were recorded significantly lower seed and biological yields over 60/30 and 30/60 flat and furrow land configurations. Oil content did not vary among the land configurations while oil yield was highest with 30/60 flat configuration over others. Production efficiency was highest with 30/60 flat than other land configurations. Interestingly, superior yield obtained treatments recorded significantly lower harvest index in mustard than flat 30cm and ridge 30/60 land configurations. Land configurations assisted with drip liners attained significantly (P≤ 0.05) higher net returns of ₹ 102 × 10^3/ha, B:C of 5.31 and profitability index of 706 ₹/ha/day were recorded with flat sowing of 30/60cm and it was at par with 60/30cm (₹ 95 × 10^3/ha, 4.96 and 656 ₹/ha/day, respectively) over other land configurations (Table 5). Cost of cultivation under drip irrigation was low due to, the cost of drip system was not included by presuming that the government subsidy is available from 50-100 % under various schemes. Therefore, land configuration of flat sowing 30/60 and 60/30 cm with one drip lateral between two rows were resulted in maximum profitability in terms of net

Table 5 Net returns, gross returns, cost of production, B:C and profitability index of Indian mustard under drip irrigation under different land configuration (Pooled mean of 2 years)

Treatment	Net returns (₹/ha)	Gross returns (₹/ha)	Cost (₹/ha)	B:C	Profitability index (₹/ha/day)
Flat (30CM)	73286^{b}	94116^{b}	20829	3.62^{b}	505^{c}
Ridge 30/60	76520^{b}	99850^{bc}	23329	2.88^{b}	528^{c}
Furrow 60/30	74681^{b}	98011^{bc}	23329	2.76^{b}	515^{c}
Furrow 90/60	39766^{a}	63096^{a}	23329	1.65^{a}	274^{b}
Flat 60/30	95070^{bc}	115899^{bc}	20829	4.96^{c}	656^{cd}
Flat 30/60	102419^{c}	123248^{c}	20829	5.31^{c}	706^{d}
Flat 90/60	26061^{a}	46891^{a}	20829	1.29^{a}	180^{a}

Within column, value represents with different letter indicate significant difference (P<0.05) returns and B:C from Indian mustard under limited irrigation conditions. Likely, 30 to 34% highest net returns obtained under flat 60/30 and 30/60 land configurations over furrow and ridge at 30/60 and 60/30 due to highest seed yield. In addition to the reduced water consumption, drip irrigation also helps to reduce the cost of cultivation in operations, such as fertilizers, labour, tilling and weeding, when compared with the conventional irrigation (Narayanamoorthy 2009). Severe water scarcity, increased cost of cultivation and low productivity and profitability from crop cultivation are the root cause for farmers distress (Deshpande and Arora 2010), which can be reduced substantially through irrigation innovation.

From the above findings it can be concluded that, adoption of drip irrigation at 30/60cm and 60/30cm flat land configurations enhances all the growth and yield parameters besides enhancing seed and oil productivity. Continues availability of moisture in the flat 30/60 and 60/30 land configuration enhances root parameters by increasing photosynthetic activity in plants. Adoption of drip irrigation at flat 30/60 and 60/30cm found beneficial to the farmers in terms of economics and utilizing the available resources efficiency. Under arid and semi-arid conditions where severe water scarcity exists, drip irrigation with flat land configuration at 30/60 and 60/30cm could minimize the evaporation losses though efficiently utilizing the plants.

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