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Research Communication

Deficit-irrigation management and agri-horti system compatibility using drip for enhancing water-use efficiency and profitability in Indian mustard (*Brassica juncea*)

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ABSTRACT

A field experiment was carried out in a split-plot design during the winter (*rabi*) season of 2020 at New Delhi, to evaluate the effect of different agri-horti system (AHS), viz. moringa (*Moringa oleifera* Lam.), *phalsa* (*Grewia asiatica* L.), *karonda* or Carandas plum (*Carissa carandas* L.), aonla Indian gooseberry (*Phyllanthus emblica* L.) and guava (*Psidium guajava* L.) and 3 deficit-irrigation scheduling (DIS), viz. rainfed, 0.4 irrigation water: cumulative pan evaporation (IW : CPE) ratio and 0.6 IW : CPE ratio on Indian mustard [*Brassica juncea* (L.) Czern. & Coss.]. The yield attributes and yield of Indian mustard were significantly influenced by AHS under various deficit irrigation scheduling (DIS). Significantly higher seed yield (1,939 kg/ha), stover yield (6,067 kg/ha), and biological yield (8143 kg/ha) were recorded under moringa-based AHS. In case of DIS, 0.6 IW : CPE resulted in the maximum yield followed by 0.4 IW : CPE and rainfed. The maximum net returns were obtained in case of (₹52,516/ha) 0.6 IW : CPE. The best monetary efficiency was achieved with the 0.6 IW : CPE treatment (₹438/ha/day), followed by the 0.4 IW : CPE treatment (₹410/ha/day) and rainfed (₹333/ha/day).

Key words: Deficit irrigation scheduling, Agri-Horti system, Water-use efficiency, yield

Indian mustard is one of the most important economic winter (*rabi*) season oilseed crops, mainly grown in arid and semi-arid region of India. In India, the crop is grown over a 6.0 million ha area, yielding 7.98 (million tonne) and 1,324 kg/ha economic output (GoI, 2018). In India, productivity of Indian mustard is generally lower than that of other advanced nations because of inappropriate water management. Indian mustard is mostly farmed in deficit-irrigation system (DIS) and regularly experiences drought-like conditions throughout the critical crop-growth phase (Rathore *et al*., 2014). Deficit-irrigation scheduling is a significant aspect impacting mustard yield since excessively water application results in wastage, while insufficient water application results in yield reduction. As a result, there is a pressing need to positively impact use of water resources through increasing water efficiency. In these scenarios, where agricultural resources are limited and shrinking, the demand to produce more food with less resources such as land, labour, water, fertilizer, and pesticides arises. In this regard, agri-horticulture-based production systems have been shown be more climate-responsive, as well as ensuring higher system productivity and profitability. Nutrient pumping from the soil, inclusion of leaf litter thus increasing soil organic carbon, root networks reducing leaching loss, improving physical properties of soil, biological nitrogen fixation, protecting the soil from erosion, increased biological activity and reliability of the rhizospheric environment, and so on are some of the advantages of this Agri-Horti system (Lehmann and Schroth, 2003). Guava, *karonda*, aonla, *phalsa*, and moringa are among of India's major tropical and subtropical fruits. Owing to their ability to tolerate moisture stress, heat, cold salinity, and other climatic and soil variables, they are effectively cultivated in a wide range of environments and soil conditions (Kaushik and Kumar, 2003). Hence a study was carried out on deficit-irrigation management and agri-horti system compatibility using drip for enhancing water-use efficiency and profitability in Indian mustard.

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During the winter (*rabi*) season 2020–2021, the experiment was conducted on Research Farm of the Division of Agronomy at the ICAR-Indian Agricultural Research Institute, New Delhi. (28° 40' N, 77° 12' E, and 229 m above mean sea-level), having a semi-arid climate. The field has a level topography and a well-designed drainage system. The experimental site was sandy-loam soil, with *p*H 7.8, poor in available N (145 kg/ha) and organic C content (0.42%), medium in P (15.3 kg/ha) and K (210 kg/ha). The soil had a bulk density of 1.53 Mg/m^3 and an infiltration rate of 2.6–3.2 mm/hr. The total amount of rainfall received during the season was 75.9 mm. The maximum temperature recorded 33° C in March and the lowest in December. The experiment was conducted under split-plot design, consisting of 5 agri-horti system, viz. moringa, *karonda*, *phalsa*, guava and aonla based, and deficit-irrigation scheduling treatments, viz. rainfed, 0.4 irrigation water: cumulative pan evaporation (IW : CPE) and 0.6 IW : CPE, were randomly allocated to subplots and replicated 3 times. On 24 October 2020 certified seeds of Indian mustard variety 'PM 28' were sown in the alleys of horticultural crops, viz. moringa, *phalsa*, guava, *karonda* and aonla. Indian mustard was sown with 5 kg/ha seed rate at 5 cm depth with 30 cm × 10 cm row spacing with the help of seed drill. To combat the lethal diseases of stem rot and white rust, the seed was treated with carbendazim 2.0 g/kg seed and metalaxyl (Apron 35 SD) 6.0 g/kg seed before sowing. To maintain plant-to-plant distance, thinning was done 15–20 days after sowing (DAS). It was uniformly fertilized with urea, single superphosphate and muriate of potash to supply 80, 40, 40 kg/ha N, P_2O_5 and K_2O respectively. Entire amount of fertilizer was applied at the time of sowing. Normal crop husbandry was carried out for successful raising of the crop. Among different agri-horti systems, their leaf falls were collected with the help of litter traps of 1 m × 1 m size placed at 4 directions under the tree. Irrigation scheduling was carried out based on IW : CPE ratio. The rainwater was harvested and stored in the pond for providing irrigation through drip system. The depth of irrigation water applied was 20 mm through drip system. Irrigation was applied when cumulative pan evaporation value (CPE) reaches 50 mm for the treatment 0.4 IW : CPE ratio and 33.33 mm for 0.6 IW : CPE. Pan evaporation remain < 2.5 mm/day during November to February 2020–21 and higher evaporation was recorded in October and March. The mustard yield was used as the numerator, and the consumptive use (CU) of water as the denominator, to compute water-use efficiency.

$$\text{WUE} = \frac{\text{Yield}}{\text{Consumptive use of water}}$$

The least significant difference (LSD) was used to distinguish treatment means at a 5% level of significance. Only differences with a *P*d"0.05 were considered significant.

Deficit-irrigation scheduling and agri-horti system had significant influence on plant height, crop-growth rate (CGR) and dry-matter accumulation (DMA) of Indian mustard (Table 1). Different agri-horti systems significantly influenced the plant height, CGR and DMA and significantly highest and lowest value was observed under moringa and guava based agri-horti system respectively. This could be owing to the fact that moringa is a multipur-

Table 1. Effect of deficit-irrigation management and agri-horti system on growth, yield attributes and yield parameters of Indian mustard

Treatment	Plant height (cm)	Dry-matter accumulation (g/plant)	CGR (g/m^2)	Siliqua/ plant	Primary branches	Secondary branches	Seed/ siliqua	Seed yield (kg/ha)	1,000-seed weight
Agri-horti system									
Moringa based	163.6	74.20	1.82	408	7.78	18.67	15	1,939	4.61
Phalsa based	157.2	69.62	1.75	379	7.11	18.33	15	1,700	4.47
Karonda based	151.8	65.74	1.67	352	7.33	17.44	14	1,634	4.37
Aonla based	146.9	63.09	1.56	298	6.67	15.67	13	1,602	4.04
Guava based	140.3	55.27	1.33	248	6.44	14.78	12	1,467	3.44
SEm±	2.7	1.86	0.09	6.14	0.14	0.47	0.44	41.33	0.18
CD (P=0.05)	8.8	6.07	0.28	20.01	0.47	1.52	1.44	134.8	0.59
Deficit-irrigation scheduling									
Rainfed	141.7	54.00	1.13	261	6.07	15.53	11	1395	3.73
0.4 IW : CPE	153.0	67.80	1.82	354	7.20	17.60	14	1712	4.05
0.6 IW : CPE	161.2	74.96	1.93	396	7.93	17.80	17	1899	4.78
SEm±	1.6	1.04	0.05	3.83	0.22	0.25	0.26	27.04	0.14
CD (P=0.05)	4.7	3.08	0.16	11.3	0.65	0.74	0.77	79.77	0.42

CGR, Crop-growth rate; IW : CPE, irrigation water : cumulative pan evaporation pose tree that can fix a considerable amount of nitrogen from the atmosphere in the soil (Melesse *et al.,* 2012). Applications of irrigation water increased the plant height significantly and the highest value was found with 0.6 IW : CPE treatment followed by 0.4 IW : CPE and rainfed treatments. Water supply with irrigation during a critical period of Indian mustard [30 days after sowing (DAS)] provided a conducive growth environment, resulting in such a rise in plant height. With no irrigation scheduling, the plant height may decrease due to potentially exposing the crop to increased water stress at its key stage of water requirement. Agri-Horti system increased the DMA/plant significantly and the trend of DMA was in the order of moringa > *phalsa* > *karonda* > aonla > guava based agri-horti system. As moringa plants are higher than mustard crops, there was less competition between them, leading to increased DMA, plant height, CGR, and canopy spread in terms of higher leaf-area index (LAI). Guava has such an allelopathic effect, causing DMA and crop growth to suffer. Application of irrigation water significantly increased the DMA/plant and highest amount was recorded under 0.6 IW : CPE treatments followed by 0.4 IW : CPE and rainfed. Water supply at crucial growth phases (30 DAS) provide a favourable environment for cell turgidity, cell enlargement, cell growth, and photosynthate portioning, resulting in increased plant growth and development (Chauhan *et al.,* 2002).

Different yield attributes, viz. number of primary and secondary branches, siliqua/plant, seeds/siliqua, and 1,000-seed weight, were significantly influenced by different agri-horti systems and deficit-irrigation scheduling (Table 1). Different agri-horti system influenced the yield attributes significantly and maximum result was obtained with moringa-based agri-horti system over *phalsa*, *karonda*, guava and aonla. This might be owing to higher plant growth and development under moringa system because of its substantial benefits towards mustard plant as compared to other horticultural crops taken along side. Application of irrigation water with 0.6 IW : CPE resulted in the maximum yield attributes over 0.4 IW : CPE and rainfed. This could be because more irrigations and a larger amount of water were applied, which encouraged the development of primary and secondary branches and, as a result, higher numbers of siliqua/branch by maintaining a better soil-moisture regime. Better moisture availability owing to irrigation not only increased the yield-attributing parameters but also enhanced the nutrients availability which perhaps resulted in more branches/plant and siliqua/plant. The 1,000 seed-weight increased greatly as a result of improved moisture and nutritional availability, resulting in improved photosynthate translocation from source to sink.

All the agri-horti systems significantly influenced the seed yield of Indian mustard. Among different agri-horti systems, moringa-based one recorded the highest seed yield followed by *phalsa*, *karonda*, *aonla* and *guava* based system. The result might be owing to higher number of primary and secondary branches, siliqua/plant and seeds/siliqua under moringa-based system. On the other hand, application of irrigation water at 0.6 IW : CPE ratio recorded the maximum seed yield followed by 0.4 IW : CPE and rainfed treatments. This might be owing to higher availability of water under 0.6 IW : CPE compared to 0.4 IW : CPE and rainfed condition. More moisture availabil-

Table 2. Effect of deficit irrigation management and agri-horti system on water-use parameters of Indian mustard

Treatment	WUE (kg/ha-mm)	IWUE (kg/ha-mm)	MWUE (₹/ha-mm)	MIWUE (₹/ha-mm)	Net returns (₹/ha)
Agri-horti system					
Moringa based	9.1	27.9	852.7	551.2	59,188
Phalsa based	8.0	24.6	705.7	438.4	48,613
Karonda based	7.8	23.7	665.6	432.3	45,702
Aonla based	7.6	23.3	644.9	410.7	44,291
Guava based	7.0	21.3	557.0	345.9	38,317
SEm±	0.20	0.61	27.08	16.62	1,829.00
CD (P=0.05)	0.65	2.00	88.31	54.21	5,964.69
Deficit-irrigation scheduling					
Rainfed	6.8	-	578.5	-	39,915
0.4 IW : CPE	8.1	28.5	820.6	371.3	49,235
0.6 IW : CPE	8.8	23.7	656.5	357.3	52,516
SEm±	0.13	0.41	18.01	11.17	1,196.56
CD (P=0.05)	0.38	1.20	53.14	32.95	3,529.86

WUE, Water-use efficiency; IWUE, irrigation water-use efficiency; MWUE, monetary water-use efficiency; MIWUE, monetary irrigation water-use efficiency ity to plants might have led to production of more photosynthates, which have aided in the transfer of more photosynthates to the seeds. Despite the fact that Indian mustard has a low water need (25–35 cm), water stress during a few crucial stages of the crop has resulted in a considerable drop in growth and productivity (Pradhan *et al*., 2014; Rathore *et al.,* 2017). The water-use efficiency of the moringa-based agri-horti system was the highest, followed by the *phalsa*, *karonda*, *aonla*, and guava-based agri-horti systems. This was owing improved water-use by mustard plants, which resulted in enhanced plant growth and development under moringa-based agri-horti system.

The economic analysis showed that the moringa-based agri-horti system ensued the highest gross and net returns, followed by *phalsa*, *karonda*, *aonla* and guava (Table 2). The outcome could be attributable to increased biomass buildup and canopy spread in moringa-based system as a result of accessible soil moisture. Another factor is that there was less competition between the trees and the Indian mustard crop, resulting in increased growth and seed yield. Higher profits were ensured by integrating applicable tree species with complementary intercrops. Same study reported by Rathore *et al.,* (2017). Deficit irrigation at 0.6 IW : CPE, on the other hand, resulted in significantly greater gross returns and net returns than at 0.4 IW:CPE and rainfed.

Thus, it can be concluded that among different agri-horti systems and deficit-irrigation scheduling practices, moringa-based agri-horti system and 0.6 IW : CPE enhanced water-use efficiency and profitability of Indian mustard crop. With the use of proper irrigation-water scheduling, limited irrigation water can be used to achieve high seed yield and water productivity under Indian mustard crop.

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