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Response of irrigation scheduling with hydrogel under deficit and sufficient irrigation conditions on Indian mustard (*Brassica juncea*) in semi-arid India

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ABSTRACT

In the Gird Agroclimatic Zone at Rajamata Vijayaraj Scindia Krishi Visva Vidhyalay, Zonal Agricultural Research Station Morena, an experiment was carried out during the Rabi season of 2013–14, 2014–15, and 2015–16. Split plot design was used to set up the experiment, with three hydrogel levels assigned to each sub-plot and four watering schedules assigned to the main plots, all of which were reproduced three times. The growth and yield parameters of mustard (Brassica juncea L.) were significantly higher when irrigation was scheduled at 0.8 IW/CPE. These attributes were plant height, number of primary branches plant^{-1}, number of siliquae plant^{-1}, number of seeds siliqua-1, and seed yield (1803 kg ha^{-1}). In a similar vein, the irrigation schedule at 0.8 IW/CPE across the remaining treatments resulted in better oil yield (781.8 kg ha^{-1}), financial returns, production efficiency (15.1 kg ha^{-1}day^{-1}), and B:C Ratio. When compared to the other treatments, the irrigation schedule with rainfed (no irrigation) had the highest water use efficiency (8.5 kgha-cm). As the hydrogel level was increased to 5.0 kg ha^{-1}, growth metrics, yield attributes, seed yield, and oil production all improved. Higher production efficiency (14.3 kg ha^{-1} day^{-1}) and water use efficiency (9.5 kg/ha-cm) were also brought about by the increased yield with 5.0 kg ha^{-1} hydrogel.

Keywords: *Economic, Hydrogel, Indian mustard, Irrigation scheduling, Production efficiency, Water use efficiency, B:C Ratio and Seed Yield*

Introduction

Vegetable oil has one of the highest shares (40%) of the production of all agricultural commodities globally. India is the largest importer of edible oils ($10.5 billion) in the world followed by China & the USA. India's share of world edible vegetable oil imports is about 15% (FAO 2019). Indian vegetable oil economy is the world's fourth-largest after the USA, China, and Brazil with total oilseed production of 34.2 million tonnes (Mt) during 2019–20. Oilseed cultivation is undertaken across India in an area of 26.0 Million hectares (Mha), mainly on marginal lands, dependent on monsoon rains (un-irrigated), and with low levels of input usage. Indian mustard (*Brassica juncea L.)* is an important winter (rabi) season oil seed crop. It is also known as Rai or Laha. In India, it is believed to be an introduction from China. It has been grown for oilseed, greens and as a spice. Oilseed crops occupy a significant place in the Indian economy, next to food grains. Rapeseed-mustard is the third most important oilseed crop grown in the world after soybean (*Glycine max*) and palm (*ElaeisguneensisJacq.*) oil.

India is an important rapeseed mustard growing country in the world, occupying the third position in its production after Canada and China of the seven edible oilseeds cultivated in India, the contribution of rapeseed-mustard (*Brassica spp.*) is 28.6% in the total production of oilseeds. After soybean, which accounts for 27.8% of the country's oilseed economy, it is the second-most significant edible oilseed in India [5]. In India, oilseeds make up 13.33% of all cropland, with rapeseed and mustard accounting for more than 3%. Rapeseed and mustard are produced on 6.1 Mha of land, producing 8.3 Mt of cropland annually with an average productivity of 1349 kg ha^{-1} [5]. In Madhya Pradesh, 691 thousand hectares of rapeseed and mustard are produced, yielding 928.03 thousand tonnes of product with an average productivity of 1343 kg ha^{-1} [5].

Sound management practices for rapeseed-mustard are needed for efficient use of limited moisture, available during the crop season especially at critical stages of crop growth, high evaporative demand (2-6mm day^{-1}), low (<0.25%) soil organic carbon, and poor crop management, which are restricting the national average productivity of oilseed Brassicas to 1.09 t ha^{-1}, as compared to the world's average of 1.83 t ha^{-1} [20], [33], [23] in India. Efficient irrigation water management in rapeseed-mustard has an enormous impact on seed and oil products and also on response to other applied inputs [33]. Besides efficient irrigation water management, improved rainwater and soil moisture conservation help in enhancing crop growth and yield as well. The successful cultivation of the crops in semi-arid areas during rabi (winter season) is mainly dependent upon the

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conserved soil moisture of the previous Kharif (rainy season). In this scenario, superabsorbent polymers (hydrogels) may be of high significance. In mustard-growing areas, generally, irrigation during the crop period is being practiced. However, mustard crop cultivation with only one-irrigation, to be the worst management through the check basin method, is responsible for lower water-use efficiency (WUE) of 35–40% [35]. Irrigation through check basins often results in the excess water supply at one stage and moisture deficit at the other growth and phenological stages, eventually consequence in poor growth and photosynthetic rate, less branching, and finally lower seed yield [43]. Recent advances in water management, such as precise irrigation scheduling, fertigation, and the use of superabsorbent polymers with high water holding capacity, biocompatibility, and synthetic flexibility, provide new hope for improving crop productivity and water use efficiency (WUE) in the face of diminishing water resources by enhancing water relations in sandy soils [37], [10], [51]. The application of synthetic polymers increases plant water availability in situations where irrigation water supply is limited by preventing water from draining past the root zones [29]. In addition to extending the irrigation interval, these polymers capture stored rainwater and other moisture and progressively release it later on to meet the crop's water needs [13], [4]. By stopping leaching, the hydrogels lessen nutrient losses, particularly those of nitrogen and potassium. As crop plants require nutrients, it thus encourages synchronization in nutrient release and absorption [32]. Increased biomass output [11], [52] and improved seed germination and seedling survival [19], [1] when polymers are used boost yield [36]. Hydrogel remains non-toxic and harmless until it breaks down completely into carbon dioxide, water, and ions of potassium and ammonium [25] [46]. However, there are contrasting reports also which have shown little to no response of hydrogels [17]; [48]; [21]; [31], thus, its agronomic evaluation on drought mitigation and impact on yield, keeping the crop, soil texture, and type, and weather in consideration, is urgently needed to develop efficient irrigation scheduling under limited water resources. Under adequate irrigation conditions too, hydrogel could prove to be beneficial as the number of irrigations could be cut down accordingly in stead of the moisture retained by the hydrogel in soil. Given the above, the present study was undertaken for growth, productivity enhancing water-use efficiency of Indian mustard under semi-arid conditions.

2. Materials and methods

2.1. Prevailing weather and site description

The weather conditions during the growing season of the crop have been described in Table -1. The maximum temperature ranged between 23.9–40.1^{0}C ,26.0-37.5 and 25.6–37.0^{0}C during 2013–14, 2014–15 and 2015-16 respectively, and minimum temperature ranged between 6.5-20.9, 6.2-18.6 and 6.1-20.4^{0}C respectively. Rainfall data were recorded using a rain gauge installed at the experimental site (monthly rainfall data has been provided in Table-1). During 2013–14,'2014-15 and 2015-16, 22.0, 25.7and 14.7 mm respectively rainfall were received in during crop season, that too in February coinciding with the terminal stage of the crop. During 2014–15, a comparatively higher ambient temperature at crop establishment period led to higher moisture stress consequent to evaporative losses during 2013–14, maintaining a favorable soil moisture regime during the important phenological crop growth phases (Table- 1). The study was carried out at the RVSKVV – ZARS Morena in India, which is located 174.31 metres above mean sea level at latitudes 250 15 to 260 45N and longitude 70030E. Gird Agro-climatic zone is the classification given to the study region. This region has a semi-arid climate, which is very hot in May and June and chilly in December and January. Conducting experiments in the winter months of 2013–14, 2014–15, and 2015–16. The soil of the experimental field was sandy loam in texture of old alluvial plain and having electrical conductivity (EC) 0.33 dS m^{-1}, pH 7.80 of 1:2 soil-water ratio, soil organic carbon stock (SOC) 6.45 Mg ha–^{1}, low in organic carbon (OC) content (0.28%), available N (185 kg ha^{-1}), P (9.1 kg ha^{-1}), S (9.5 kg ha^{-1}), and Zn (0.50 mg kg^{-1}), whereas medium in available K (191 kg ha^{-1}), and Cu (0.33 mg kg^{-1}), Fe (6.6 mg kg^{-1}) and Mn (4.2 mg kg^{-1}) above their critical limits for deficiency The bulk density of the soil was 1.52 Mg m^{-3} and the infiltration rate 4.7 mm h^{-1} . Soil moisture at field capacity wilting point was 26–28%, 6.5–7.6%, whereas, hydraulic conductivity was 6.5–7.3 cm/s.

2.2. Treatment description, the record of observations, and crop management

Strip plot design was used for the tests, and four different irrigation management strategies were used: unirrigated, irrigation schedule at IW/CPE ratios of0.4,0.6, and 0.8, and hydrogel levels (0, 2.5, and 5.0 kg ha^{-1}) that were duplicated three times. When the CPE (mm) reached a predetermined value, 20 mm of irrigation water was applied for a particular IW/CPE ratio. An open pan evaporimeter from the weather observatory provided the CPE values. The hydrogel belongs to the polyacrylate family and is super-absorbent, based on biopolymers. The gel is made by polymerizing acrylamide in a free radical solution, grafting it onto a cellulose derivative with about 50% add-on, and then cross-linking it. It is known as superabsorbent hydrogels since it can absorb more than 350–500 g of water per gramme of xerogel (dry polymer) [16]. Prior to seeding at the time of the final ploughing, the hydrogel was thoroughly mixed into the top 8–10 cm of the soil. Table 2 provides further crucial attributes of the hydrogel. The SAP-hydrogel was applied in powdered form at the rate of 2.5 and 5.0 kgha^{-1} and mixed with the dry seed. The hydrogel was applied along with the seed through a mustard seed drill in the field. The mustard crop cv. RVM-2 was sown in the winter season (the IInd to IIIrd week of October) during three study years. The seeds were sown at the rate of 5 kg ha^{-1} at 30 X 10 cm spacing at a depth of 3–4 cm with a seed drill. The seeds were treated with metalaxyl 35 WS) 6.0 g kg^{-1} seed for protection against stem rot and white rust diseases, respectively, before sowing. The plant-to-plant distance was maintained at 10–15 cm by thinning 15–20 DAS (days after sowing). The nitrogen dose was 80 kgha.$^{-1}$ Phosphorus (P_2O_5, 40 kg ha^{-1}) as di-ammonium phosphate and potassium (K_2O 40 kg ha^{-1}) as muriate of potash were applied as basal at the time of land preparation. Half a dose of N and a full dose of P and K were applied as basal, whereas the remaining in the form of urea was applied through broadcasting. The crop was harvested and the seed and biomass yields were recorded plot-wise. The volume of water applied under the irrigation scheduling in mustard was done based on IW/CPE value. various IW/CPE ratios were calculated as per the procedure described by [7] in Irrigation Water Management Training Manual No. 3. The total amount of water applied (input water) was computed by summing up irrigation water and rainfall. The total water balance was computed considering the irrigation water applied contribution from rainfall and water productivity. The tensiometers (36) were installed at a depth of 0–30 cm, as >70% of water is being absorbed by the plant from this depth.

The soil moisture tension was recorded at regular intervals with the help of tensiometers, which had a range of matric potential from 0-100 cb (centibar). The relative water content (RWC) in mustard leaf was measured at pre-flowering stages and it is estimated in % from fresh, dry, and turgid weight of the leaf.

Table:2 - Important characteristics of Pusa-hydrogel.

Parameters	Characteristics
Chemical constitution	Cellulose based grafted and cross-linked anionicpolyacrylate
Appearance	Amorphous, granulous
Particle size	20-100 mesh (micro-granules)
pH	7.52
Stability at 50^{o}C	Stable
Minimum absorption in deionized water	350 g g^{-1}
Sensitivity to UV light	None
Temperature of maximum absorption	50 ^{o}C
Time taken for 60% swelling	2 h. (Approx.)
Stability in soil	<2 years
Toxicity in soil	None

2.3. Data collection and statistical analysis

To analyse the amount of accessible N, P, and K, 36 soil samples from each plot were collected between 0 and 15 cm down. The pH, EC, and salt load (TDS) of the irrigation water were also examined. A water metre installed in the mainline was used to quantify the amount of water used for irrigation. Main shoot length (M S), Branches plant^{-1}, total siliquae plant^{-1}, 1000 seed weight (g), Seed yield (kg ha^{-1}), Biological yield (kg ha^{-1}) and Oil yield (kg ha^{-1}) were among the yield parameters, phenology, and growth observations that were noted. The minimum support price of mustard was used to calculate the cost of cultivation following the recommendations set out by the Government of India's Commission of Cost and Prices. The B:C ratio was then obtained by dividing the net returns from the cost of cultivation. Both soil moisture tension and soil moisture content were measured depth-wise using tensiometers and the gravimetric technique on a weight basis. 36 samples were used to estimate the volumetric soil moisture during the pre-flowering stages. Data on yield attributes, production efficiency, and economics were pooled and analyzed while the remaining data were analyzed on yearly basis were statically analysed and interpreted as suggested by [14].

Results and Discussion

Growth parameters

The plant height and dry matter accumulation both were influenced by irrigation scheduling and hydrogel application. Application of irrigation remained significantly superior over no irrigation in terms of plant height and dry matter accumulation (Table-3). The different levels of IW/CPE scheduling, however, remained statistically at par owing to high rainfall and low evaporation rates subsequently during the crop growth period. Application of hydrogel (5.0 kgha^{-1}) increased the plant height and dry matter accumulation significantly over no hydrogel application. However, it remained at par with that of 2.5 kg hydrogelha^{-1}. The increase in plant height was due to water supplies with irrigation at a critical stage providing a congenial growth environment which improved the cell elongation, cell turgidity, opening of stomata, and finally the partitioning of photosynthates efficiently to the sink [9]. Shorter plant height with no irrigation might be due to water stress at its critical stage of water requirement. The application of super absorbent increases all agronomic traits of crops [26]. Accumulation of more dry matter irrigation and hydrogel application could be attributed to the increased plant height and morenumber of branches per plant (Table -3) arising out of the better growth and development conditions facilitated by desirable moisture supply at its critical stage.

Yield attributes

The yield attributes, viz. primary and secondary branches per plant, siliquae per plant and 1000-seed weight were influenced significantly with irrigation and hydrogel application (Table 3).

When compared to no irrigation, irrigation greatly increased the number of branches per plant, siliquae per plant, and 1000-seed weight. However, for the previously mentioned reasons, irrigation scheduling based on IW/CPE ratio did not differ considerably. These outcomes closely match [39] findings. In terms of siliquae per plant and 1000-seed weight, yield attributes were recorded at their highest with an application of 5.0 kg hydrogel ha^{-1}, and were significantly better than those of 2.5 kg hydrogel ha-^{1}. When compared to no irrigation and no hydrogel application, irrigation plus hydrogel application generated higher yield qualities. This may be because the improved moisture regime maintained by the increased moisture availability encouraged the growth of branches. In addition to promoting plant growth and development, the application of hydrogel and irrigation guaranteed increased nutrient availability, which resulted in the production of more branches and, ultimately, improved sink development and a bigger number of siliquae per plant. Greater nutrient availability and improved photosynthetic translocation from source to sink may be the cause of the 1000-seed weight increase. Higher photosynthetic accumulation in the seeds following irrigation and hydrogel application may also contribute to this effect. Reports from [30] and [50] have found similar results.

Seed and Oil yield studies

Seed yield was influenced significantly with irrigation and hydrogel application (Table 3).Application of irrigation increased the seed yield significantly over no irrigation. Oil yield differences among the various treatments(Table 4) on irrigation scheduling based on IW/CPE ratio were not recorded as significant as those treatments stood out to be practically the same owing to sufficient rainfall received in the crop growth period, which did not let any further irrigation be required after the one applied at 30 days stage. The maximum seed and oil yield was achieved with 5.0 kg hydrogelha^{-1}, which remained substantially superior over that of 2.5 kilogramme hydrogel ha^{-1}. The application of hydrogel boosted seed and oil production significantly over no hydrogel. The increased number of siliquae per plant and the 1000-seed weight may result in a significant gain in seed and oil yield [12].

Water use efficiency

Both the timing of irrigation and the application of hydrogel had a substantial impact on the WUE (Table 4). When compared to no irrigation, irrigation greatly boosted the WUE. Since there was no room for further watering due to the low levels of evaporation, the IW/CPE-based irrigation scheduling did not differ statistically. Hydrogel application up to 5.0 kg ha^{-1} greatly enhanced WUE. Seed production and water consumption by agricultural plants are the two main factors that determine water-use efficiency. If irrigation and 5.0 kg hydrogel ha^{-1} result in higher yields compared to no irrigation and no hydrogel application, respectively, then water-use efficiency may have improved. The authors [26] have reached similar conclusions.

Economic studies

Application of irrigation registered a significantly higher benefit-cost ratio (B: C ratio) over that of no irrigation (Table 4). The irrigation scheduling that produced the highest B: C ratio, at 0.8 IW/CPE, was also shown to be considerably better than no watering. The benefit-cost ratio could not be considerably affected by the use of hydrogel.In comparison to the unirrigated condition, the production efficiency (PE) of mustard irrigated at 0.8 IW/CPE ratio was 20.88% higher (Table 4). The use of hydrogel resulted in a larger (12.6%) rise in PE compared to the absence of hydrogel treatment. Higher PE in mustard is a result of the hydrogel application's increased yield. In addition to increasing yields, it implies that using hydrogel can conserve irrigation water.

Relative Water Content (RWC) and soil moisture dynamics

The highest RWC was recorded with irrigation at 0.8 IW/CPE ratio and lowest in rainfed conditions. The application of hydrogel 5.0 kg ha^{-1} higher RWC and lowest in control. The soil moisture content at 45 DAS stage is highest in frequently irrigated at 0.8 IW/CPE ratio and lowest in rainfed conditions. The application of hydrogel 5.0 kg ha^{-1} higher soil moisture content and lowest in without application (Table 4)

4. Discussion

The water-laden gel 'chunks' formed from Hydrogel after contact with water act as local miniature water reservoirs which helps in the initial establishment of crops resulting in better crop growth. According to [42], the plant can more effectively use the moisture in the root zone during fewer irrigation cycles when there is a higher soil moisture retention following the application of hydrogel and its slow release over an extended period of time. Higher soil moisture and optimally translocated nutrients—cum-photosynthates—mediated by hydrogel application enhance plant growth and development in oilseed crops grown under restricted irrigation and rainfed circumstances [33]. Applying hydrogel improves plant longevity [49] produces more dry matter, and extends the stay-green quality [8], especially in conditions when moisture is limited [51]. In hydrogel-amended plots, improved nutrient availability through a longer duration of water availability and uptake enhances plant growth and yield qualities [33]. The application of super absorbent polymers improves cell membrane development, leaf area index, leaf area duration, chlorophyll, and protein content by balancing nutrient substances and higher CO_2 fixation through prolonged stomata opening ascribes for the increase in yield attributes of mustard [33]. Moisture deficiency at the critical stages reduces the plant crown diameter and at the siliquae development stage, even if siliquae formation is there, the siliquae length significantly reduces. The large quantities of water and nutrients retained near the rhizosphere zone with hydrogel applications are released in synchrony with plant demand [6]. Because the hydrogel makes it possible for plants to draw water and nutrients from deeper and wider soil depths, it improves the uptake of nutrients including calcium, magnesium, phosphorus, potassium, and nitrogen, leading to improved growth and yield characteristics [24]. The decreasing TSW under hydrogel application in rainfed and sufficient irrigation conditions increases in order, suggesting a greater benefit of hydrogel use in moisture-stressed conditions. Hydrogel applied spotlessly in moisture-stressed conditions initially helps plants emerge early and establish seedlings; but, as more secondary branches are produced, the TSW decreases. Higher output can be attained by improving soil cluster structures and water-retention capacity through the application of hydrogel, which also promotes improved root development and plant growth regulation [2]. [42] have demonstrated comparable yield advantages and higher nutrient uptake outcomes in mustard. Pusa hydrogel is capable of holding water 300–500 times its weight and the gradual release of moisture helps in retaining soil moisture towards the maturity stage of the crop which prolongs the seed filling and oil bio-synthesis period [41]. Not only oil content, but the quality of the oil is also positively influenced by the hydrogel. Hydrogel application increases sink capacity in the plant which provides enough time to prepare unsaturated fatty acids from the saturated fatty acids in mustard [45]. The moisture absorbed by polymer from the surrounding soils is maintained near the seed surface, which execrates germination and enhances the total number of germinated seeds [2]. The modified cation exchange capacity of the soil and enhanced nutritional and water status of plants through hydrogel as a soil conditioner and ameliorant further improve soil aeration and soil-microbial activities. [18] found that it increases sorption capacity, nitrogen uptake, and yield by delaying the dissolving of fertilizer. Indirect nutritional benefits are provided by a hydrogel-assisted, beneficial soil-water-plant continuum, in addition to increased moisture availability, which improves yields [38]. Consequently, the economy benefits from greater fertilizer recovery [22]. Soil amended with hydrogel has a greater capacity to retain water, allowing for the cultivation of many plants with much reduced watering requirements and associated savings on irrigation expenses. Economic benefits may accrue from using hydrogel under low irrigation regimes, according on the total B:C ratio. Sandy soils have reduced deep percolation, evaporation, seepage, and surface runoff losses; so, hydrogel-embedded soils retain moisture. In soil that is both moist and appropriate for their growth, they create a network of expanding cells that can hold water and plant nutrients in solution, which they then release to the plants when they need it [40]. The swelling of hydrophilic polymers adds additional water storage space to the plant-soil system, which in turn reduces plant water stress. Plants in soil treated with hydrogel wilt at a slower rate than plants in soil without hydrogel due to poorer hydraulic conductivity and less water drainage below the root zone [13], [29]. Gravitational water immediately penetrates into the soil profile and is inaccessible to plants; however, the hydrogel can hold this water through deeper and denser roots [33]. It improves the hydraulic conductivity, wilting point, rate of infiltration, and moisture content at field capacity of the soil, which in turn increases its capacity to transmit water [3], [15]. Plants can absorb more water because of this. Hydrogel maintains a favorable soil moisture balance even when irrigation intervals are lengthened. Soil water release per unit of suction changes is approximately four times higher in sandy soils with hydrogel added compared to soils without hydrogel in the water availability range of plants (10-100 kPa). Hydrogel, as stated by [29], delays the arrival of the critical soil moisture constant and increases the gap between irrigations. As a result, crop water needs can be reduced by 55 to 80% in terms of both the quantity and frequency of irrigation [42].

The improvement in soil physical properties, including mean weight diameter of soil aggregates, water-stable structural units, relative field capacity, retention pores, and structural coefficient. At the same time, it reduces transmission pores, penetration resistance, and saturated hydraulic conductivity [28]. Hydrogel holds great promise in reducing soil moisture tension by improving soil moisture under moisture-stressed conditions [47]. Super absorbent polymers decrease the frequency of irrigation by increasing irrigation interval, therefore water cost and energy will be saved [44]. The positive energy balance is the outcome of increasing the water storage capacity of soil consequent to hydrogel application [34], [35], [27].

Conclusion

Based on the findings that were acquired throughout the experiment, it is clear that watering during the critical stage continues to be a useful strategy for increasing the seed yield of Indian mustard. It is possible that the utilisation of a starch polymer such as hydrogel could be beneficial in terms of enhancing soil moisture and achieving a greater seed yield; however, due to the higher costs associated with its utilization; its utilization should be optimized.

Future Scope

Indian mustard (*Brassica juncea*) is a major oilseed crop in India, especially in semi-arid regions. These regions have issues such as restricted water supply and high evapotranspiration rates, necessitating effective water management measures. Incorporating hydrogels into irrigation schedules could provide a solution to these issues. So, the future of employing hydrogels in irrigation scheduling for Indian mustard in semi-arid India looks promising. Hydrogels are an important tool in sustainable agriculture because they have the ability to improve water retention, crop yields, and reduce water stress. However, substantial study, economic analysis, and practical implementation strategies are required to fully realize their potential and secure farmer acceptance in water-stressed regions.

Declarations

Conflict of Interest: The authors declare no competing interests.

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Author Contribution: SST[1], JS, ST and RY: Data collection, paper preparation, methodology and interpretation. RKN, PKS, SST[2]: Conceptualization, incorporation of recent data and data modification. RB and HT: Editing, reviewing, paper correction and formatting. All authros agreed with the final draft.

Table:3. Growth parameters, yield attributes and yield (3 years pooled) of Indian mustard as Influenced by irrigation scheduling and hydrogel levels

Treatment	Plant Height (cm)	Dry matter accumulation per plant (g)	Primary branches plant^{-1}	Secondary branches plant^{-1}	SiliquaePlant^{-1}	1000 seed wt. (g)	Seed yield (kg ha^{-1})	Biological yield (kg ha^{-1})
Irrigation level								
No Irrigation	190.9	36.2	5.8	8.4	190.2	4.38	1495	47242
0.4 IW/CPE Ratio	201.5	41.1	7.1	9.8	218.4	4.75	1631	5277
0.6 IW/CPE Ratio	203.8	41.8	7.3	10.4	226.8	4.87	1780	5789
0.8 IW/CPE Ratio	204.7	42.4	7.5	10.9	235.7	5.12	1803	6219
Sem±	1.3	0.3	0.2	0.2	4.3	0.11	52	112
CD(5%)	4.02	1.1	0.6	0.6	13	0.42	172	352
Hydrogel levels kg/ha								
0	193.8	37.6	5.8	8.6	198	4.56	1528	5364
2.5	198.9	40.2	7.0	10.2	220	4.77	1680	5455
5.0	201.1	41.4	7.6	11.2	236	4.92	1808	5524
Sem±	1.7	0.6	0.2	0.3	3.0	0.1	47	98
CD(5%)	4.6	1.6	0.5	0.8	8.0	0.42	201	412

Table :4. Oil yield (kg ha^{-1}), WUE (kg/ha^{-cm}),B:C Ratio,PEKg ha^{-1} day^{-1}, RWC% (at 45DAS) and Soil moisture content (%) (At 45 DAS) in Indian mustard as influenced by irrigation scheduling and hydrogel levels (Pooled data of 2013-14, 2014-15, 2015-16)

Treatment	Oil yield (kg ha^{-1})	WUE (kg/ha^{-cm})	B:C Ratio	PE Kg ha^{-1} day^{-1}	RWC% (at 45DAS)	Soil moisture content (%) (at 45 DAS)
Irrigation level						
No Irrigation	604.5	0.85	0.55	12.5	70.2	12.9
0.4 IW/CPE Ratio	655.2	0.77	1.01	13.3	81.7	15.4
0.6 IW/CPE Ratio	619.5	0.71	1.15	14.1	87.5	16.8
0.8 IW/CPE Ratio	781.8	0.65	1.25	15.1	91.4	17.5
Sem±	12	-	0.05	0.41	-	-
CD(5%)	48.8	-	0.18	1.45	-	-
Hydrogel levels kg/ha						
0	614.1	0.76	0.94	12.7	64.8	12.9
2.5 kg ha^{-1}	675.60	0.84	0.81	13.5	75.2	13.4
5.0 kg ha^{-1}	772.60	0.95	0.78	14.3	83.4	15.8
Sem ±	8	-	0.04	0.35	-	-
CD(5%)	22.4	-	NS	1.25	-	-

Table:-1. Weather conditions during crop period in 2013-14, 2014-15 and 2015-16.

Month	Temp(°C)						Mean RH (%)						Rainfall (mm)			Pan Evaporation (mm day^{-1})		
	Max			Min			07.20 h			14.20h								
	2013-14	2014-15	2015-16	2013-14	2014-15	2015-16	2013-14	2014-15	2015-16	2013-14	2014-15	2015-16	2013-14	2014-15	2015-16	2013-14	2014-15	2015-16
October	34.1	36.2	37.0	20.9	18.6	20.4	75.1	67.2	61.2	56.3	42.3	42.3	-	-	-	7.0	5.8	3.7
November	32.0	34.9	30.5	13.3	13.4	14.4	67.4	68.1	64.4	39.9	40.1	38.1	-	-	7	4.2	3.0	6.7
December	29.6	28.5	28.7	9.5	8.4	6.1	76.6	76.1	76.1	40.1	43.7	56.7	-	8.5	5	2.4	2.2	4.1
January	23.9	26.0	25.6	6.5	6.2	7.4	79.6	85.1	88.3	47.6	46.4	69.3	22	1	-	1.2	2.4	1.2
February	29.6	29.4	29.9	9.5	9.4	8.7	84.9	67.1	83.7	55.3	31.4	67.6	-	16.2	-	2.5	4.1	4.8
March	40.1	37.5	36.4	11.2	14.7	14.3	66.1	59.4	82.2	32.7	30.5	71.2	-	-	2.7	7.6	8.0	9.4

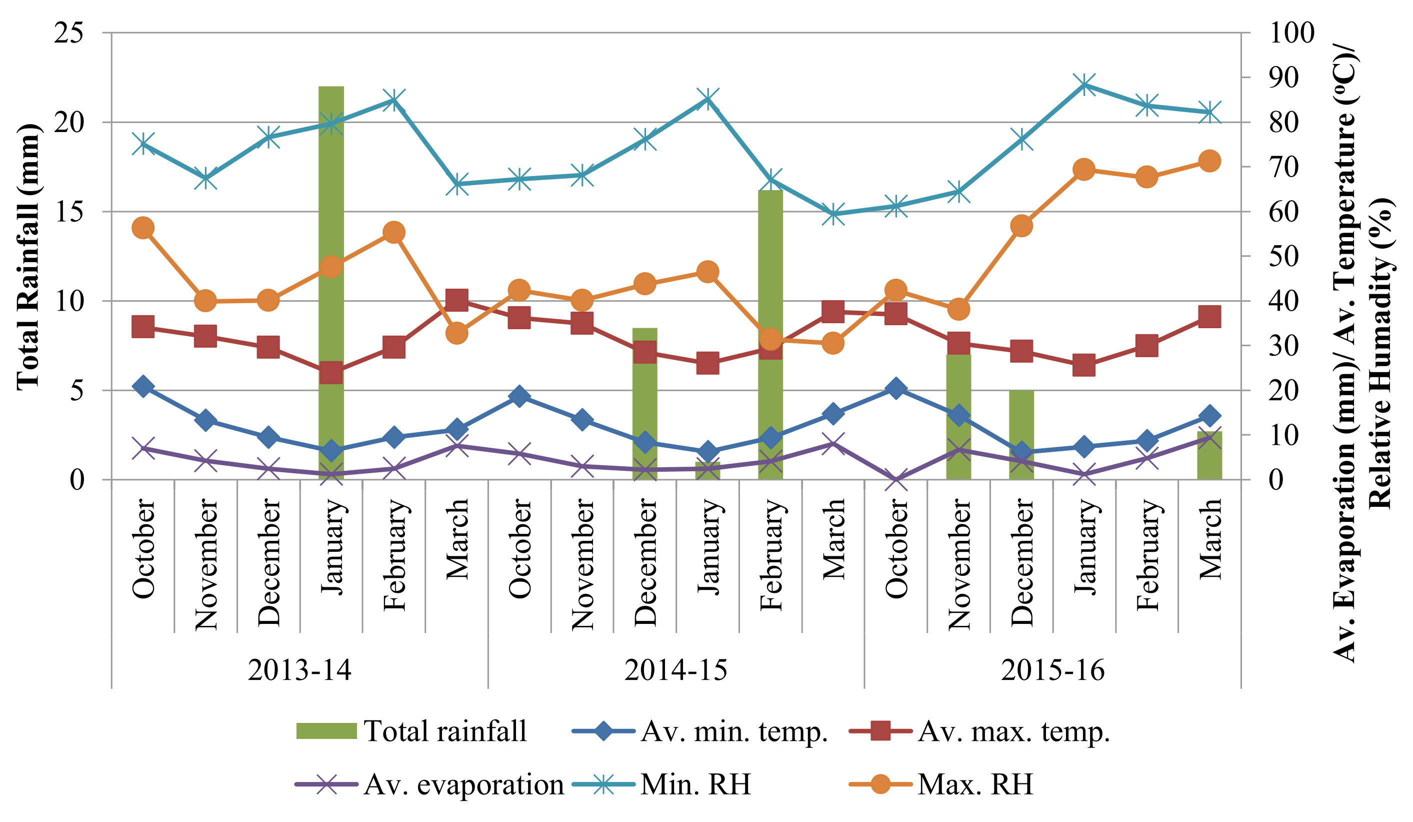

Fig.1: Weather conditions during crop period in 2013-14, 2014-15 and 2015-16.

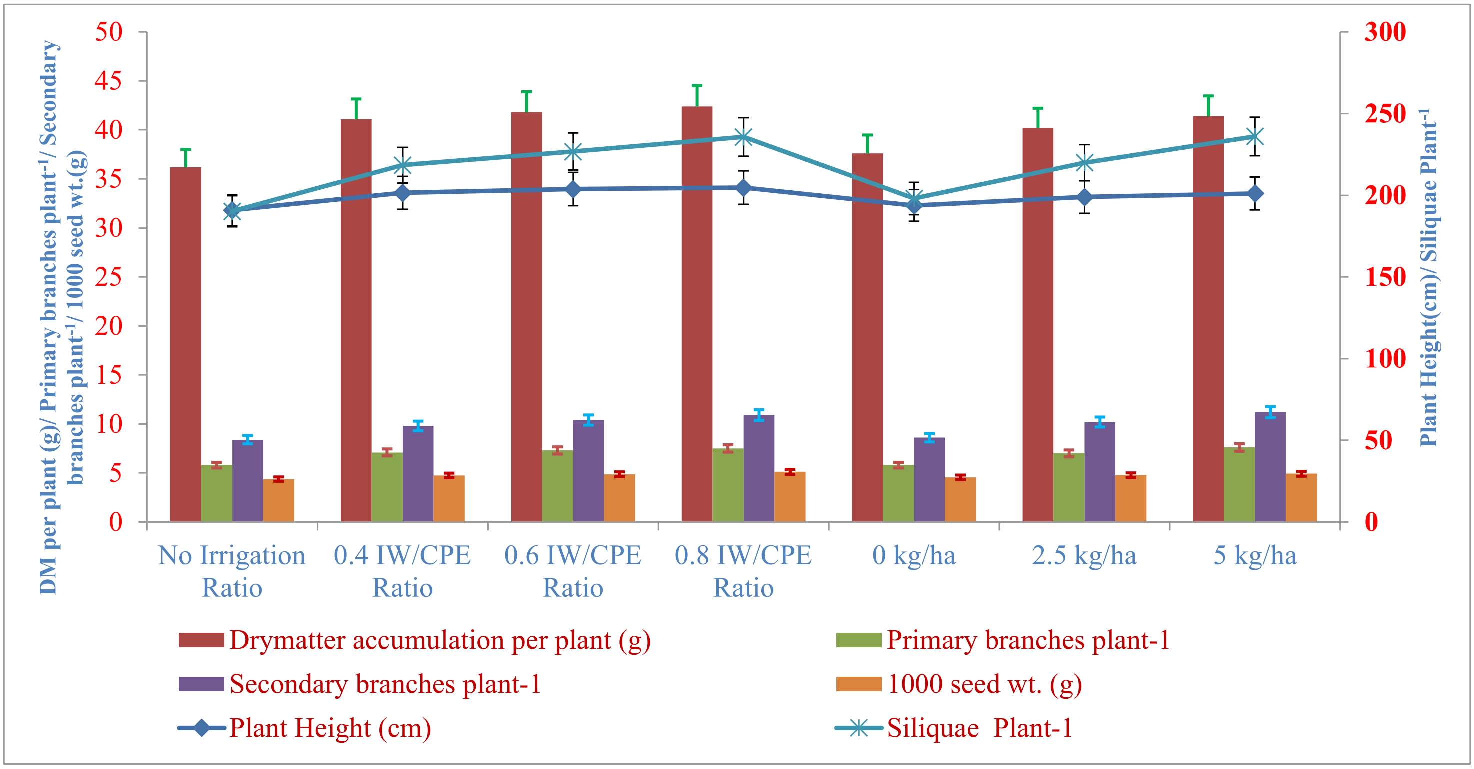

Fig .2: Growth parameters, yield attributes and yield (3 years pooled) of Indian mustard as Influenced by irrigation scheduling and hydrogel levels

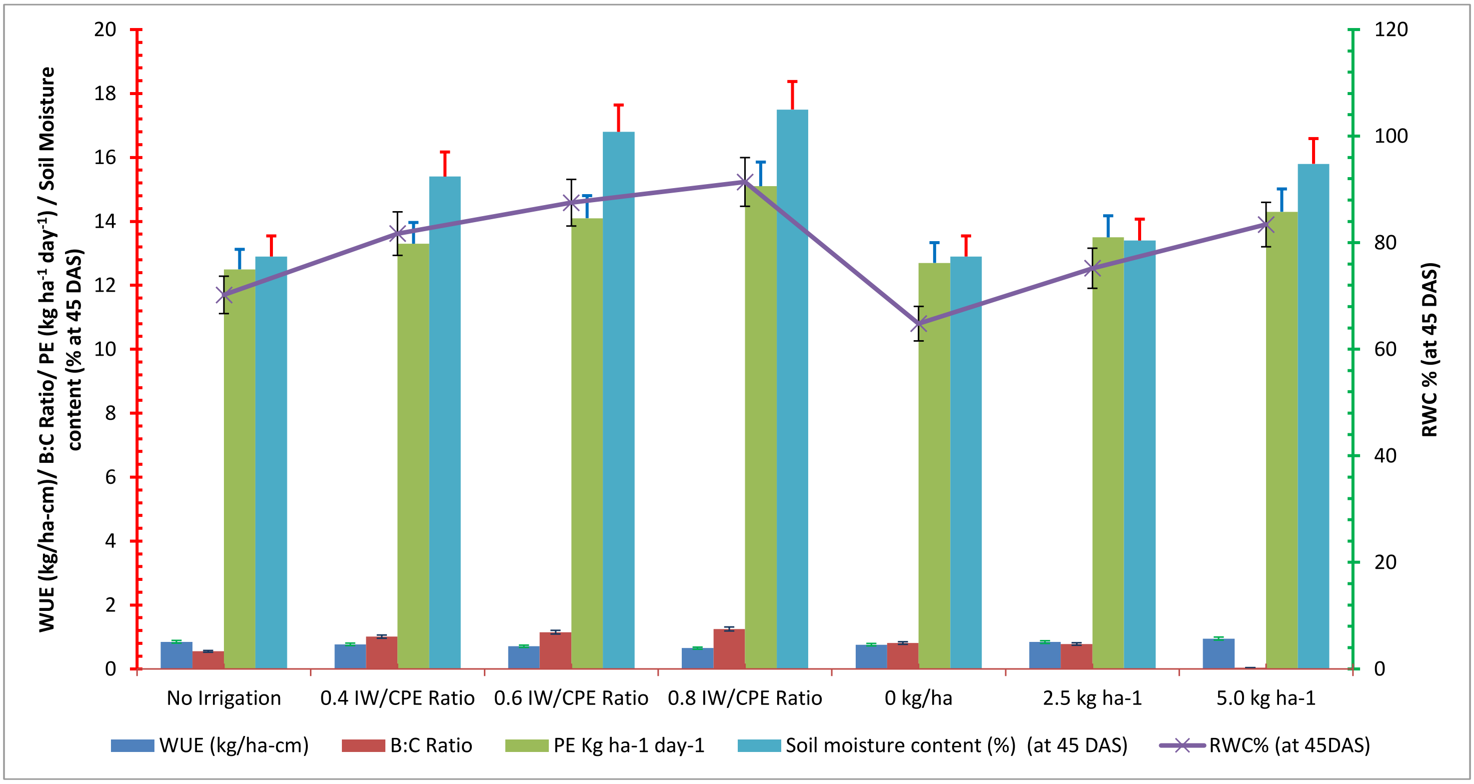

Fig. 3: WUE (kg/ha-cm), B:C Ratio, PEKg ha-1 day-1, RWC% (at 45DAS) and Soil moisture content (%) (At 45 DAS) in Indian mustard as influenced by irrigation scheduling and hydrogel levels (Pooled data of 2013-14, 2014-15, 2015-16)

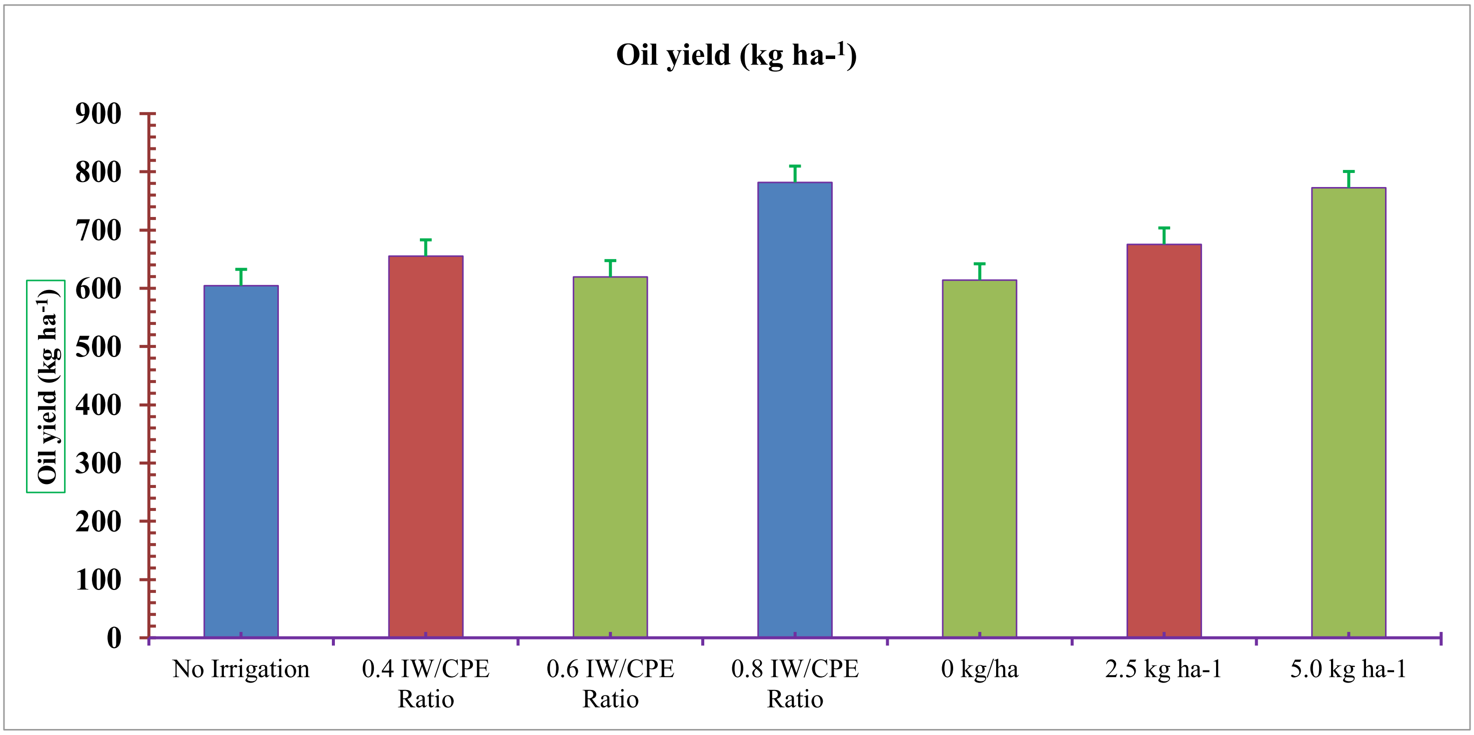

Fig. 4: Oil yield (kg ha^{-1}), in Indian mustard as influenced by irrigation scheduling and hydrogel levels (Pooled data of 2013-14, 2014-15, 2015-16)

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