Enhancing Productivity and Water Use Efficiency of *Zaid* Mungbean (*Vigna radiata* L.) Through Sprinkler Irrigation, Fertility Amendments and Bio-regulator

ABSTRACT

An experiment was conducted on mungbean (*Vigna radiata* L.) during three consecutive years of *zaid* (2016 to 2018) at Agricultural Research Station, Ummedganj, Kota (Rajasthan). The experiment consisted of 12 treatment combinations including three irrigation regimes (IW/CPE ratio 0.8, 1.0 and 1.2) and four fertility amendments along with foliar spray of bio-regulator (100 % RDF, 100 % RDF + salicylic acid 100 ppm, 125 % RDF + salicylic acid 100 ppm and 150% RDF + salicylic acid 100 ppm) were under taken in split plot design with four replications. The maximum grain yield (930 kg ha^{-1}) was recorded under application of IW/CPE ratio 1.2 over IW/CPE ratio 1.0 and 0.8. Significantly higher WUE (2.04 and 2.03 kg ha-mm^{-1}) and WP (0.204 and 0.203 kg m^{-3}) were recorded under irrigation regime of IW/CPE ratio 1.2 and 1.0 in comparison to IW/CPE ratio 0.8. Significantly higher net return (Rs. 37409/- ha^{-1}) and B:C ratio (1.89) were recorded under irrigation regime of IW/CPE ratio 1.2 over irrigation regimes of IW/CPE ratio 1.0 and 0.8. The maximum grain yield (830 and 840 kg ha^{-1}) was recorded with the application of 125 % RDF + foliar spray of salicylic acid 100 ppm remained on par with 150 % RDF + foliar spray of salicylic acid 100 ppm, but it was found significantly superior over application of over application of 100 % RDF + foliar spray of salicylic acid 100 ppm and 100 % RDF. Significantly higher water use efficiency (2.06 kg ha-mm^{-1}) and water productivity (0.206 kg m^{-3}) were recorded in mungbean with the application of 125 % RDF + foliar spray of salicylic acid 100 ppm over application of 100% RDF + foliar spray of salicylic acid 100 ppm and 100 % RDF in mungbean. Application of 125 % RDF + foliar spray of salicylic acid 100 ppm gave maximum net return (Rs. 31272/- ha^{-1}) and B:C ratio (1.59) over application of 100% RDF + foliar spray of salicylic acid 100 ppm and 100 % RDF.

Key words: Fertility levels, irrigation regimes, mungbean, salicylic acid, water use efficiency.

INTRODUCTION

Mungbean (*Vigna radiata* L.) is an important pulse crop mainly grown in arid and semi-arid region of India. Mungbean is a typically warm season crop it requires 60-65 days from sowing to maturity and also tolerate higher temperature and can be successfully grown during *zaid*. The excellent source of quality protein 25 per cent, fat 1.3 per cent, minerals 3.5

per cent, fibers 4.1 per cent and carbohydrates 56.7 per cent. It also contains 75 mg calcium, 8.5 mg iron and 49 mg β-carotene per 100 g of a split dal [1]. "Indian farmers covered 30.84 lakh ha under pulses in which around 16.10 lakh ha was covered in mungbean. The state of Rajasthan (18.30 lakh ha), Maharashtra (3.28 lakh ha), Karnataka (2.89 lakh ha), Odisha (1.63 lakh ha) and Telangana (0.70 lakh ha) are the major producer of mungbean in India" [2].

Mungbean cultivation during *zaid* season after wheat and mustard harvest is an important practice to improve soil fertility in those areas where paddy-wheat and soybean-mustard crop rotation is used. The optimum sowing time of *zaid* mungbean is the month of mid-March, early sowing of *zaid* mungbean can reduce the germination whereas delayed sown crop can be damaged by the monsoon rains during end of June. Irrigation water is the limiting and costly input in *zaid* season so its judicious application need special attention for the maximizing of yield and water use efficiency per unit area and per time, hence it is necessary to find out suitable approach for sprinkler irrigation regime of mungbean[3].

"Fertilizer management is one of the important factors for improving crop productivity" [4]. "Nutrients is essential for normal growth and development of green gram. Phosphorus promotes early root formation and the formation of lateral, fibrous and healthy roots which is very important for nodule formation and to fix atmospheric nitrogen. It also induces root proliferation and nodulation" [5]. "The low yield of mungbean is not only due to its cultivation on marginal land, but also because of inadequate and imbalanced fertilization. Phosphorus is an important plant nutrient and it affects seed germination, cell division, flowering, fruiting, synthesis of fat, starch and infect most biochemical activities" [6].

"Growth regulators are known to influence a wide array of physiological parameters like alteration of plant architecture, assimilate partitioning, promotion of photosynthesis, uptake of nutrients, enhancing nitrogen metabolism, promotion of flowering, uniform pod formation, increased mobilization of assimilates to defined sinks, improved seed quality, induction of synchrony in flowering, and delayed senescence of leaves" [7]. "Salicylic acid (2-hydroxybenzoic acid), as a natural plant hormone, has many effects on physiological processes and growth of plants" [8]. Furthermore, salicylic acid has an important role in tolerance of some environmental stresses such as heat, salts, and drought stress. [9] revealed that "foliar application of salicylic acid influences different physiological and biochemical aspects of mungbean plant via increasing assimilation rate which revealed increasing in chlorophyll content and hill reaction activity in the leaf".

MATERIALS AND METHODS

An experiment was conducted on mungbean during three consecutive years of *zaid* (2016 to 2018) at Agricultural Research Station, Ummedganj, Kota (Rajasthan). In Rajasthan, this region falls under Agro-climatic zone-V (Humid South eastern Plains) of Rajasthan. This zone possesses typical sub-tropical conditions with maximum temperature range in summer is 42.2- 43.0 ^{0}C and minimum 12 - 27^{0}C. In this zone annual average rainfall is received 840 mm. The soil of experimental site was clay loam in texture, slightly saline in reaction, medium in available nitrogen (264 kg ha^{-1}) and phosphorus (21.7 kg ha-1) while high in potassium (388 kg ha-1) and sufficient in DTPA extractable micronutrients with pH (7.61) and EC (0.52 dS m^{-1}). Source of nutrients were applied urea for nitrogen, DAP for phosphorus and mutate of potash for potassium. The full dose of fertilizer 100 % RDF (20:40:30 NPK kg ha^{-1}) was applied as basal dose. Irrigation was applied by sprinkler as per irrigation regimes of the experiment and one foliar spray of salicylic acid 100 ppm was applied at flowering stage.

The experiment consisted of 12 treatment combinations including three irrigation regimes (IW/CPE ratio 0.8, 1.0 and 1.2) allocated in main plots and four fertility levels along with foliar spray of bio-regulator (100 % RDF, 100 % RDF + foliar spray of salicylic acid 100 ppm, 125 % RDF + foliar spray of salicylic acid 100 ppm and 150% RDF + foliar spray of salicylic acid 100 ppm) in sub plots were under taken in split plot design with four replications. Data on grain yield was recorded plot wise after harvest as per standard procedures. Water use efficiency, water productivity and monetary return were also determined by appropriate procedure. The data were statistically analysed by adopting appropriate method of standard analysis of variance [10].

Irrigation water use efficiency was estimated as the ratio of seed yield (kg/ha) and irrigation water applied (mm) based on below formula.

WUE = Seed yield (kg/ha) /Irrigation water applied (mm)

Water productivity is defined most often a s the average amount of output per unit of water applied on a field or per unit of water evapotranspiration.

WP (kg/ha) = Output (kg/m^{3})/ Water applied (m^{3}/ha)

RESULTS AND DISCUSSION

Effect of irrigation regimes

Grain yield

It is obvious from the data presented in Table 1. showed that grain yield of *zaid* mungbean increased significantly with the increasing of irrigation regimes. The maximum grain yield (930 kg ha^{-1}) was recorded under application of IW/CPE ratio 1.2 over IW/CPE ratio 1.0 and IW/CPE ratio 0.8 (820 and 630 kg ha^{-1}). Significantly higher yield of mungbean might be owing to the availability of optimum moisture in the root zone of crops through small and repeated irrigation which checks percolation losses beyond the root zone depth and prevent drying up of upper soil layers thus ensure proper conditions for maximum utilization of soil available nutrients and applied fertilizer nitrogen. Optimum moisture condition in the root zone of soil influences the nodulation and availability of different nutrients and helps in achieving better plant growth and yield. The results are in closely conformity with the findings of [11] and [12].

Water use efficiency

It is evident from data presented in Table 1. showed that the water use efficiency and water productivity were significantly influence under various irrigation regimes. The maximum WUE (2.04 kg ha-mm^{-1}) and WP (0.204 kg m^{-3}) was recorded under irrigation regime of IW/CPE ratio 1.0 in comparison to IW/CPE ratio 0.8 (1.85 kg ha-mm^{-1}) and WP (0.185 kg m^{-3}). However, it was found at par with irrigation regime of IW/CPE ratio 1.2 (2.03 kg ha-mm^{-1} and 0.203 kg m^{-3}). The WUE of the soil in *zaid* mungbean crop was found non-significant but nitrogen availability significantly increases with increase Etc ratio [13]. This could be due to the fact that the yield produced in higher levels of irrigation is in proportionate to water used by the crop [14]. The decrease in water productivity with increasing irrigation levels has been reported by [15] in mungbean.

Monitory return

The critical appraisal of pooled data presented in Table 2 revealed that monetary return was significantly influence with different irrigation regimes. Significantly higher net return (Rs. 37409/- ha^{-1}) and B:C ratio (1.89) were recorded under irrigation regime of IW/CPE ratio 1.2 over irrigation regimes of IW/CPE ratio 1.0 (Rs. 30937/- ha^{-1} and 1.61) and IW/CPE ratio 0.8 (Rs. 20216/- ha^{-1} and 1.08). This might be due to more seed and straw yield under irrigation schedules as compared to rest of irrigation schedules, values of this increased yield to greater proportion to the increase in cost of cultivation due to adoption of higher irrigation levels. These findings are agreed with the results of [16] and [17].

Effect of fertility levels and bio regulators

Grain yield

A perusal of pooled data presented in Table 1. revealed that significantly increasing grain yield of *zaid* mungbean with the increasing of fertilizer levels along with foliar spray of bio regulator. The maximum grain yield (830 kg ha^{-1}) was recorded with the application of 125 % RDF + foliar spray of salicylic acid 100 ppm remained on par with 150 % RDF + foliar spray of salicylic acid 100 ppm (840 kg ha^{-1}). However, it was found significantly superior over application of over application of 100 % RDF + foliar spray of salicylic acid 100 ppm (780 kg ha^{-1}) and 100 % RDF (720 kg ha^{-1}) grain yield in the pooled analysis.

"It might be due to higher supply of nutrients, crops synthesized more photosynthates and the storage organ was better developed. Nitrogen is closely linked to control the vegetative growth of plant and hence determines the fate of reproductive cycle. The increases in yield as a result of nitrogen application" have also been reported by [18]. "Phosphorus in soil, being a major structural element of cell and helped in cell elongation, greater availability of photosynthates, metabolites and nutrients to develop reproductive structures which ascribed to increased growth parameters and lead to higher yield attributes and yields of mungbean crop. These results are in conformity with those reported by [19] in mungbean".

"Foliar application of salicylic acid might have enhanced the CO_2 fixation, induced activity of carbohydrate synthesizing enzymes coupled with effective partitioning of dry matters into reproductive sink as reported earlier" [20]. "The production of higher seed yield due to growth regulators may be attributed to the fact that plants treated with growth regulators remained physiologically more active to build up sufficient food reserves for developing flowers and seeds. Earlier studies, in the case of green gram also, foliar application of brassinolide and salicylic acid could be beneficial for improving yield and nutritional quality of green gram" [20]. [21] also reported that "application of 125 ppm salicylic acid to black gram plants increased seed yield".

Water use efficiency

It is further clearly visible from the data presented in Table 1. the water use efficiency and water productivity of *zaid* mungbean significantly increase with the increasing levels of fertilizer along with foliar spray of salicylic acid. Significantly higher water use efficiency (2.06 kg $ha\text{-}mm^{-1}$) and water productivity (0.206 kg m^{-3}) were recorded in mungbean with the application of 125 % RDF + foliar spray of salicylic acid 100 ppm remained on par with application of 150 % RDF + foliar spray of salicylic acid 100 ppm (2.10 kg $ha\text{-}mm^{-1}$ and 0.204 kg m^{-3}). However, it was found significantly superior over application of 100% RDF + foliar spray of salicylic acid 100 ppm (1.95 kg ha-mm^{-1} and 0.195 kg m^{-3}) and 100 % RDF (1.79 kg ha-mm^{-1} and 0.179 kg m^{-3}) water use efficiency and water productivity in mungbean.

"The improvement in water productivity with an increase in nitrogen fertilization might be attributed to increased leaf area which leads to reduction in evaporation component of evapotranspiration, smaller increase in evapotranspiration compared to yield and better utilization of available soil water. The results were in agreement with the findings of" [12]. "It was hypothesized that fennel is a plant species of high-water use efficiency and that the application of plant growth regulators can improve water use efficiency and grain production under water deficit, depending on the phase of plant development. However, any factor that causes an increase in yield or decrease in water used can increase water use efficiency" [22]. The water use efficiency of fennel was significantly improved by the application of the plant growth regulators used. This improvement in the water use efficiency, especially at the vegetative stage, was mainly caused by less water consumption by plants, probably due to a decrease in transpiration rate following application of plant growth regulators.

Monetary return

It is obvious from data presented in Table 2. the net return and B:C ratio of *zaid* mungbean significantly increase with the increasing levels of fertilizer along with foliar spray of salicylic acid. Application of 125 % RDF + foliar spray of salicylic acid 100 ppm and 150 % RDF + foliar spray of salicylic acid 100 ppm was found at par in terms of net return (Rs. 31272/- and 31554/- ha^{-1}) and B:C ratio (1.59 and1.56) over application of 100% RDF + foliar spray of salicylic acid 100 ppm (Rs. 29025/- ha^{-1} and 1.52) and 100 % RDF (Rs. 26231/- ha^{-1} and 1.45) net return and B:C ratio in the pooled analysis.

This might be due to more grain and straw yield under 125% RDF compared to 100 % RDF, values of this increased yield to greater proportion to the increase in cost of cultivation due to adoption different doses of fertilizer. These findings are agreed with the results of [23] and [24]. "Some of the earlier study also reported that foliar spray of DAP, NAA and micronutrients significantly improved seed yield of mungbean and highest benefit cost ratio" [25]. "The lowest B:C ratio of 1.98 was recorded in 100% recommended dose of NPK. The application of growth regulators can increase plant tolerance to stress conditions, such as water deficit, and thereby improve plant growth and yield" [26]. Furthermore, application of growth regulators increased the production of secondary metabolites in some plant species [27].

CONCLUSION

Based on three years pooled data in *zaid* mungbean crop, sprinkler irrigation at IW/CPE ratio of 1.2 and 125 % RDF (25 N: 50 P_2O_5: 37 K_2O kg/ha) along with foliar spray of 100 ppm salicylic acid at flowering stage gave higher grain yield, water use efficiency and monetary return. Therefore, growing of *zaid* mungbean was found more productive and profitable under South-Eastern Rajasthan.

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Table 1: Effect of irrigation regimes, fertility levels and bio-regulator foliar spray on grain yield and water use efficiency of *zaid* mungbean.

Treatment	Grain yield (kg ha^{-1})				WUE (kg ha-mm^{-1})				Water productivity (kg m^{-3})			
	2016	2017	2018	Pooled	2016	2017	2018	Pooled	2016	2017	2018	Pooled
A. Irrigation regimes												
IW/CPE 0.8	610	630	650	630	1.78	1.85	1.92	1.85	0.178	0.185	0.192	0.185
IW/CPE 1.0	790	820	840	820	1.98	2.04	2.10	2.04	0.198	0.204	0.210	0.204
IW/CPE 1.2	910	930	960	930	1.97	2.03	2.08	2.03	0.197	0.203	0.208	0.203
SEm±	22	20	23	19	0.04	0.05	0.05	0.04	0.005	0.005	0.005	0.004
CD (P=0.05)	60	59	65	56	0.13	0.15	0.15	0.12	0.015	0.016	0.015	0.013
B. Foliar fertilization												
100 % RDF	700	720	740	720	1.73	1.79	1.85	1.79	0.173	0.179	0.185	0.179
100 % RDF + foliar spray of thio- salicylic acid 100 ppm	760	780	800	780	1.89	1.95	2.00	1.95	0.189	0.195	0.200	0.195
125 % RDF + foliar spray of thio- salicylic acid 100 ppm	800	830	850	830	2.00	2.06	2.12	2.06	0.200	0.206	0.212	0.206
150 % RDF + foliar spray of thio- salicylic acid 100 ppm	820	840	870	840	2.04	2.10	2.16	2.10	0.204	0.210	0.216	0.210
SEm±	13	16	17	14	0.03	0.04	0.04	0.03	0.004	0.004	0.005	0.003
CD (P=0.05)	41	50	53	45	0.10	0.12	0.13	0.10	0.013	0.012	0.014	0.011

Table 2: Effect of irrigation regimes, fertility levels and bio-regulator foliar spray on monetary return of *zaid* mungbean.

Treatment	Net return (Rs. ha^{-1})				B:C ratio			
	2016	2017	2018	Pooled	2016	2017	2018	Pooled
A. Irrigation regimes								
IW/CPE 0.8	18848	20206	21593	20216	1.01	1.08	1.15	1.08
IW/CPE 1.0	29497	30967	32347	30937	1.54	1.61	1.68	1.61
IW/CPE 1.2	35919	37464	38844	37409	1.82	1.90	1.97	1.89
SEm±	1120	1103	1280	915	0.04	0.04	0.05	0.04
CD (P=0.05)	3574	3443	3960	2764	0.12	0.13	0.15	0.12
B. Foliar fertilization								
100 % RDF	24791	26261	27641	26231	1.37	1.45	1.46	1.45
100 % RDF + foliar spray of thio- salicylic acid 100 ppm	27618	29038	30418	29025	1.45	1.52	1.60	1.52
125 % RDF + foliar spray of thio- salicylic acid 100 ppm	29832	31302	32682	31272	1.52	1.59	1.66	1.59
150 % RDF + foliar spray of thio- salicylic acid 100 ppm	30111	31581	32971	31554	1.48	1.56	1.63	1.56
SEm±	810	829	825	802	0.03	0.03	0.04	0.03
CD (P=0.05)	2456	2505	2512	2447	0.10	0.09	0.12	0.09