R-2584
[1-8]

REVIEW ARTICLE Agricultural Reviews

Agronomic Interventions for Higher Water use Efficiency in Greengram (*Vigna radiata*): An Overview

Anureet Kaur[1], Lovepreet Kaur[2]

10.18805/ag.R-2584

ABSTRACT

Agronomic manipulations are imperative for apposite growth of crop leading to higher yields. Various management practices like seed rate, planting time and method, plant population, intercultural practices, weed management, fertilizers and irrigation application, intercropping, mulch application for soil moisture conservation, *etc*. results in increased water use efficiency (WUE) of the crop. Also selection of crop which necessities lesser water usage for crop growth encourages diversification. Greengram is paramount preference for areas with scarcity of good quality water. Being rich in protein content and minerals, it serves the purpose of healthy regimen. Timely sown crop results in better growth due to favorable climatic conditions. Whereas late sown crop is adversely affected by pest attack, temperature fluctuation *etc*. ensuing reduced water use efficiency and yield diminution. Planting method, plant population and intercultural operations are essential in agronomic point of view. Selection of apt irrigation regimes directly effects water use efficiency in any field study. As crop productivity is equal with water productivity, the efficient irrigation schedule assures water saving without affecting the crop yields. Because, where no irrigations are given, the water use may be low by the crop but, this may affect crop yields. Use of recommended fertilizers may facilitate the use of irrigation water by crop for its better growth and improved WUE. Insertion of low water requiring crop as intercrop can unswervingly increase water productivity. Applying mulch conserve moisture as its use lowers evaporation from soil surface. Usage of weed management practices conserves irrigation water as weeds compete with crop plants for water and nutrients. Wherefore, the present review will reckon upon the impact of innumerable agronomic interventions in increasing water productivity.

Key words: Greengram, Irrigation schedules, Mulching**,** Water use efficiency.

Moongbean or greengram, botanically known by the name *Vigna radiate* is considered as the third most important pulse crop of India with respect to both cultivated area and production. It is considered as an important leguminous crop of Asian countries and is one of the major component crops of various cropping systems (Uddin and Parvin, 2013). Moongbean being resistant to drought conditions, low soil fertility conditions as well as shady conditions, results in production of very nutritious and healthy seeds rich in amino acids and proteins (Jiang *et al*., 2012). Moongbean pods and sprouts are usually consumed as a vegetable and are rich source of vitamins as well as minerals. These are major source of protein for vegetarians as non-vegetarians can fulfill their protein requirement from animals.Moongbean crop is a short duration crop and being a leguminous crop, it fixes the atmospheric nitrogen. It is used as a mixed crop or an intercrop or as a rotational crop in order to improve the nitrogen status of the soil and break the disease cycle or pest cycle (Ranawake *et al*., 2011). The insertion of legumes in cropping sequence improves the soil status consequently better economic yieldsof succeeding crops. Higher yield of wheat (12.8%), barley (9.4%) and mustard (3.3%) has been reported if grown after moongbean than cotton (Kaur *et al*., 2017a and Kaur *et al*., 2018). The enhancement in percent organic content, available nitrogen, available phosphorus and available potassium content of the soil is observed where moongbean grown in *kharif* season than cotton crop (Kaur *et al*., 2017b).

[1]Punjab Agricultural University, Regional Research Station, Bathinda-151 005, Punjab, India.
[2]Department of Agronomy, Punjab Agricultural University, Ludhiana-141 004, Punjab, India.

Corresponding Author: Anureet Kaur, Punjab Agricultural University, Regional Research Station, Bathinda-151 005, Punjab, India. Email: anureet_1@pau.edu

How to cite this article: Kaur, A. and Kaur, L. (2023). Agronomic Interventions for Higher Water use Efficiency in Greengram (*Vignaradiata*): An Overview. Agricultural Reviews. doi: 10.18805/ag.R-2584.

Submitted: 12-08-2022 **Accepted:** 06-01-2023 **Online:** 14-03-2023

Adequate supply of moisture unswervingly augments the growth and dry matter production of crops in addition to obliquely increasing the availability and utilization of nutrients (Kaur and Singh,2006). It is thus normally observed that during the growth, development and crucial phase of crop maturity, if there is scarcity in the supply of water and there is reduction in the yield of the crop (Asaduzzaman *et al*., 2008). With the scarcity in the supplies of water and increase in the sectors using water, there is an urgent need of improvement in the irrigation management. So, advancement is required to increase the water use efficiency by developing the new techniques of scheduling irrigation.

Basically, the water use efficiency refers to the effectiveness with which water is delivered to the crop and how much amount of water is wasted at the various junctions before field (Israelsen, 1932). The concept of improving the water efficiency of the crop is much important for the areas with scarce water resources. The water use efficiency increases with the increase in the supply of water as well as improvement in the method of irrigation scheduling. The improvement in the water use efficiency also results in the increase in the fertilizer use efficiency of the crop subsequently improving crop yields (Sharma *et al*., 2015). The irrigated agriculture which is the major part of the total agriculture can prove to be detrimental to the environment and can risk sustainability if there is absence of appropriate management of irrigation (Buttar, 2014). Hence, there are two ways to increase the crop water use efficiency, either by increase in the yield or by saving the water (Singh *et al*., 2014a). The water use efficiency of the crop is affected by various factors like the climatic conditions (temperature, relative humidity, solar radiation, wind velocity, *etc*.) (Singh *et al*., 2012a), edaphic factors (soil texture, soil structure, soil depth, soil aggregation, *etc*.) (Singh *et al*., 2014b) and nature of the plant (plant species, plant variety, plant morphology, *etc*.) (Singh *et al*., 2008) which have direct or indirect impact on the crop growth. The major agronomic techniques for enhancing the water productivity of the crop include the laser land leveling, planting time, planting method, mulch application, selection of the crop variety and the cropping system, irrigation scheduling as well as the irrigation methods.

Agronomic practices

The crop water use efficiency can be improved by selection of a good variety of crop, by the agronomic interventions like the sowing time, planting/sowing method, seed rate, plant population, intercultural practices, weed management, application of fertilizers and irrigation, intercropping system, mulch application for soil moisture conservation, *etc*. which results in increase in the water use efficiency of the crop.

Crop variety

The cultivars or crop varieties differ from one another with respect to the yield and the water use efficiency. The cultivars/genotypes which yield more than the water use and have higher water use efficiency should be preferred (Goswami *et al*., 2017). Soni and Gupta (1999) studied the summer moong varieties and concluded that variety should be selected after analysis of area and water availability. Noorzai *et al*. (2017) evaluated the influence of various genotypes on the water use efficiency of summer mungbean. The Mash-2008 genotype recorded the highest total water use efficiency and the maximum irrigation water use efficiency. El-Nakhlawy *et al*. (2018) reported that the highest value of irrigationwater use efficiency was recorded for the MN96 cultivar under the treatment under full irrigation scheduling and the stress of water given at the vegetative stage of the crop.

Seed rate and plant population

The higher density of plants results in the reduction of the evaporation of the soil water. For such situations, the plant density which is desirable for the water available for economic yield production is recommended. The maximum yield as well as the water use efficiency is achieved only when the soil moisture level is optimum with recommended plant population and fertilization (Singh *et al*., 2012b and Singh *et al*., 2013). Since the consumptive use increases with higher plant density but the higher water use efficiency can be attributed to the positive effect of the increase in the evapo-transpiration on the yield of the crop. The research study was conducted by Hari Ram *et al*. (2018) on the loamy sand soils of Ludhiana to adjudge the effect of rate of seed application on the water use efficiency of the *kharif* mungbean crop. It was proved that the optimum seed rate application is very necessary for the improvement in the efficiency of water use. It was reported that seed rate application of 20 kg ha^{-1} results in higher water use efficiencyand higher yield of grains.

Sowing time

Amidst various agronomic manipulations, sowing time plays an imperativerole in influencing the crop yields and sowing of the next season crop, as timely sown crop will vacate the field well-timed (Buttar and Kaur, 2010). Moreover, the crop sown at the recommended time of sowing results in higher water use efficiency due to the fact that the timely sown crop ensures the optimum temperature conditions and soil physical conditions. Singh *et al*. (1998) concluded that early as well as late sown crop results in the poor crop yield and reduced water use efficiency. So, it may also be implied that the sowing dates of the crop indicates the optimum climate type for the growth and development of shoot and optimum moisture utilization by the roots under the normal conditions of rainfall.

The sowing should be carried out at the time which avoids the stress period over the crop especially during the anthesis stage of the crop. Hari Ram *et al*. (2016a) concluded that the highest water use efficiency was recorded when the summer mungbean was sown on 20th of March and so this date proved to improve the water use efficiency. The results of field study by Kaur (2014) revealed that 20th March sowing recorded significantly higher seed yield (9.3% and 20.9%) than 30th March and 10th April sowing.As total crop water use was higher under 10th April sowing date due to higher temperature conditions prevailing at that time. Therefore, water use efficiency and apparent water productivity were higher under timely sown moong (20th March).

Method of planting

The method of planting is the important agronomic practice which has a direct effect on the yield of the crop but indirect effect on the water use efficiency. The line sowing of the crop has better utilization of resources and inputs as compared to broadcasting method and so has higher yield and water use efficiency. Idnani and Singh (2008) reported that the summer greengram sown on the beds resulted in saving the water and higher water use efficiency. The crop sown on the raised beds and the water is applied to it through the furrows saving 25-30% of water.

Singh *et al*. (2006) studied the effect of planting method on the water use efficiency of summer mungbean and reported that sowing on the planting moong on furrows yielded highest and additional benefit of higher water use efficiency (53.05 kg ha^{-1} cm^{-1}) compared to flat bed (43.74 kg ha^{-1} cm^{-1})., ridge planting and irrigation on furrows (42.20 kg ha^{-1} cm^{-1}), ridge planting and alternate furrow irrigation (42.24 kg ha^{-1} cm^{-1}), respectively. They further suggested that increased consumptive use of water in furrow planting and irrigation method may be due to improved moisture supply owing to meager losses of irrigation water in furrow planting itself.

Jiang *et al*. (2012) carried out a research experiment for two consecutive years on the effect of planting method along farming practices on the spring mungbeansandy loam soils of China. They assessed that the practice with double furrows and plastic film-mulched ridge combined with the water micro- resulted in the highest water use efficiency and grain yield. A field trial was conducted by Yadav and Singh (2014) during the winters to perceive the effect of methods of planting on the water use efficiency of the green gram. It was found that the maximum water use efficiency (46.81 kg ha^{-1}) was found when the crop was planted on the raised beds and the minimum WUE (38.87 kg ha^{-1}) was found when the crop was planted on the flat beds.

Kumar *et al*. (2016) carried out the research study on the sandy loam soils of Kanpur (U.P.) to adjudge the effect of method of planting on the water use efficiency of summer greengram. They concluded that the crop sown on the raised beds yielded the maximum water use efficiency with the highest crop productivity over flat bed planting.

Praharaj *et al*. (2016) reported that highest water use efficiency was recorded under the precision tillage system followed by the laser land leveler as compared to the conventional tillage which resulted in the more use of water and drastic yield reduction.

Ehsan *et al*. (2017) testified that the line sowing of the greengram under the semi-arid conditions of Afghanistan resulted in the higher grain yield and the maximum water use efficiency than the broadcast sowing of greengram. So, the line sowing (45 cm × 5 cm) results in better use of the resources and increased efficiency.

Parihar *et al*. (2017) reported that the maize-wheat-mungbean crop rotation system on the permanent beds recorded the highest water use efficiency which was followed by the sowing of the system with the zero tillage.

An experiment was carried out by Hari Ram *et al*., (2018) on the *kharif* mungbean on the loamy sand soils of Ludhiana to study the effect of the sowing method on the yield and water use efficiency of mungbean. It was reported that the water use efficiency and grain yield were maximum for the raised bed planting than the planting done on flat beds.

Irrigation

When irrigation is considered, water losses also include the mismanagement of irrigation water from its source to the crop roots. Generally, more than 50% of irrigation water is lost at the farm level. At the watershed level, however, it may be less due to possible recoveries from the subsoil and groundwater. The increase in water use efficiency with increase in irrigation level might be due to superior grain yields.

The field trial was conducted by Singh *et al*. (1981) at the IARI, New Delhi to study the effect of irrigation and anti-transpirants on the water use efficiency of spring mungbean for consecutively two years. The results were that the irrigation applied at 0.75 bar upto the phase of flowering and then at 0.5 bar afterwards till the stage of maturity resulted in the highest consumptive use of water and the maximum water use efficiency.

The effect of irrigation was studied by Phogat *et al*. (1984) on the mungbean and proved that the water use efficiency was significantly higher for the IW: CPE ratio of 0.15 and it was followed by 0.30 IW: CPE ratio.

Pannu and Singh (1993) carried out a field experiment on the sandy loam soils of Haryana during the summer months to study the effect of irrigation on water use efficiency and yield of mungbean. From the four irrigation treatments (I_{200}, I_{300}, I_{400} and I_0 *i.e*., no post-sowing irrigation) based on the cumulative evaporation, the higher water use efficiency was recorded for the I_0 where no post-sowing irrigation was given.

Mandal *et al*.(2005) concluded that the application of no irrigation or the control treatment resulted in highest water use efficiency followed by the one irrigation given at branching, two irrigations (branching and pod formation) and three irrigations (branching, pod formation and pod development). But seed yield was significantly lowest in control and maximum in four irrigation treatment. In contrary, Singh *et al*. (2006) reported that the applications of two irrigations at the pre-flowering stage and pod filling stage resulted in higher water use efficiency than three irrigations (branching, pre-flowering and pod filling stages). Therefore, increased irrigation frequency enhanced the seasonal water use but reduced the WUE.

The research findings of Habibzadeh *et al*. (2013) conclude that the maximum water use efficiency of the ecosystem was recorded for the conditions of drought where irrigation was applied after 200 mm of evaporation as compared to well-watered irrigation plants.

The effect of irrigation scheduling of summer greengram was studied by Chaudhary *et al*. (2014) on the loamy sand soils of Sardarkrushinagar. Among four irrigation schedules (At critical growth stages, 0.6, 0.8 and 1.0 IW/CPE) highest WUE was recorded in irrigations at critical stages compared to other treatments. Singh *et al*. (2014c) evaluated the effect of irrigation scheduling (1,2,3 and 4 number of irrigations) on the water use efficiency of summer moongbean. It was reported that the water use efficiency decreased as there was increase in the number of irrigations. The maximum water use efficiency was recorded (1.94 kg/ha/mm) when single irrigation was applied at 25 days after sowing of the crop.

Yadav and Singh (2014) conducted a field experiment during the winter months on silty loam soils of UP (India) to adjudge the effect of schedules of irrigation (0.6, 0.8, 1.0 IW/CPE ratios and 10 days interval at 6 cm depth) on the WUE of the green gram. The results reported that the water use efficiency decreases as the level of irrigation was increased. The maximum water use efficiency was reported for the irrigation treatment of IW: CPE of 0.6 with the depth of irrigation of 6 cm than the other treatments.However, maximum grain yield was found with 1.0 IW/CPE ratio.

Kaur (2014) compared four irrigation schedules; I_1 (0.6 IW/CPE), I_2 (0.8 IW/CPE), I_3 (1.0 IW/CPE) and I_4 (1.2 IW/CPE) with IW=5.0 cm. Among the various irrigation schedules, treatment I_4 was at par with I_3 and produced the highest seed yield which was significantly better than I_2 and I_1. More crop water use was recorded under I_4 due to more number of applied irrigations. Nevertheless, apparent water productivity was greater under I_1 irrigation schedule.

Ahmad *et al*. (2015) reported the effect of deficit of water on the efficiency of used water of mungbean. On the sandy-clay-loam soils of Saudi Arabia, four irrigation treatments were provided to the crop depending on the interval between the two irrigations. It was observed that the maximum water use efficiency was observed when the irrigation was applied to the crop at the interval of 9 days and the amount of irrigation applied was 4000 $m^3 ha^{-1}$ with 10 irrigations. It was mentioned that the water use efficiency increased with the deficit of water.

The effect of irrigation schedules on the system of intercropping of maize and summer mungbean was studied by Roy *et al*. (2015) on the sandy loam soils of West Bengal. Highest water use efficiency was recorded when the irrigation was applied at the IW: CPE of 0.5 as compared to the maize or the system, then sole mungbean.

Kaur *et al*. (2018), compared the water expense (WE) of cotton, clusterbean and moong crops in sequence with wheat in *rabi* season. Moongbean and clusterbean recorded lower WE than cotton as lesser irrigations (1-2) are required than cotton (4-6). Therefore, replacing moongbean with cotton can save considerable irrigation water and also encourage diversification of cotton-wheat crop sequence. Kaur *et al*. (2017b) appraised three irrigation levels *viz*., Optimum: three irrigations, Sub-optimum: two irrigations and Sub-sub-optimum: one irrigation in moong variety SML 668. It was established that highest moong yield was observed under Optimum (O), which was at par with Sub-sub-optimum (SSO) level. Though, highest water expense efficiency (WEE) was recorded under SSO and lowest in Optimum level. Therefore, they concluded that same level of yield per unit of irrigation water can be obtained by even giving reduced amount of water.

Ati *et al*. (2016) reported that the irrigation application to the mungbean crop at 25% depletion from control treatment of 50% depletion resulted in highest water use efficiency of 2.94 and 2.94 kg $ha^{-1}mm^{-1}$ for both the seasons respectively.

The schedules of irrigation (0.4, 0.6 and 0.8 IW/CPE) along with the depth of irrigation (5 and 8 cm) was studied by the Kumar *et al*. (2016) in order to assess the effect on the water use efficiency of the summer greengram in Kanpur (U.P.). They concluded that the highest water use efficiency was recorded for the irrigation scheduled at 0.4 IW: CPE ratio. The irrigation depth of 5 cm recorded the higher water use efficiency than 8.0 irrigation depth.

The research findings of Praharaj *et al*. (2016) found that the irrigation application by the sprinkler irrigation methods resulted in saving the water (19.5% less water use) and improving the water use efficiency (19.1% higher WUE) as compared to the flood irrigation scheduling.

Hari Ram *et al*. (2016b) carried out a research experiment in the summer season on loamy sand soils of Ludhiana to study the effect of irrigation scheduling on the water use efficiency of the summer mungbean. From the three treatments of irrigation (two, three and four number of irrigations), the higher water use efficiency (3.17 kg ha^{-1} mm^{-1}) was recorded for the three-irrigation treatment which were applied at 25, 40 and 50 DAS.

Hari Ram *et al*. (2016a) conducted a study with four termination of last irrigation treatments viz., 45, 50, 55 and 60 days after sowing. They reported that the delay in termination of last irrigation *i.e*., 60 DAS proved significantly best in improving the water use efficiency.

Quality of water is also important aspect for growth of pulses and it has been found that pulses are sensitive to poor quality water. But, judicious use of poor quality and good quality water can yield good results. Kaur *et al*., 2016 found that pre-sowing irrigation with canal water followed by the entire irrigations with poor quality water (Tube well water; RSC 6.4 $meqL^{-1}$ and EC 2200 µmhos cm^{-1}) were at par with irrigations only with canal water in terms of grain yield of moong. Kumar *et al*., 2021 found that drip irrigation at 2-day interval along with polythene mulch improves yield as well as the water productivity of chickpea crop of Indian hill region and eastern plateau.

Fertilizers

The application of fertilizers has a great impact on the yield and water use efficiency. It has been observed that application of nitrogen, phosphorus or combination of chemical fertilizers with the organic fertilizers orbiofertilizers resulted in increase in the growth and development of the crop. The availability of nutrients is highest when the tension of the soil moisture is low resulting in the ability of the plants to absorb morenutrients from soil (Singh and Kumar 2009).

Kumar and Rana (2007) conducted a research trial on the conservation of moisture and management of nutrient practices on the intercropping system of pigeon peagreengram under the rainfedconditions on the sandy loam soil of New Delhi during the rainy season. It was observed that the application of 40 kg P_2O_5 + 25 kg S ha^{-1} + 500 g ha^{-1} phosphorus solubilizing bacteria results in the maximum value of pigeon pea-equivalent yield and higher water use efficiency than the control treatment and sole application of fertilizers.

Mandai *et al*. (2005) revealed thatincrease in phosphorus levels from 0 to 30 kg ha^{-1} towards 60 kg ha^{-1} resulted in increased consumptive use of water and water use efficiency. According to the research conducted by Singh *et al*., (2014c) on the silty loam soils of Faizabad to study the effect of phosphorus fertilizer on the water use efficiency of the summer mungbean. The application of 45 kg P_2O_5 ha^{-1} recorded the highest water use efficiency and consumptive use of water compared with 30 kg P_2O_5 ha^{-1} ,15 kg ha^{-1} and control treatments.

An investigation by Kaur *et al*., 2016, to study the residual effect of different doses of sulphur and quality of water on moong bean succeeding Indian mustard was carried in southwestern region of Punjab. It was found that grain yield was statistically similar at 20 and 40 kg S per hectare. Whereas,profile water use and water expense efficiency was maximum in 40 kg S ha^{-1}. The application of potassium fertilizer on the water use efficiency was accounted by Ati *et al*., (2016) and they reported that application of 120 kg ha^{-1} K fertilizer resulted in maximum water use efficiency than 0,40 and 80 kg K ha^{-1}.

Ehsan *et al*. (2017) conducted field research in Afghanistan to study the effect of levels of phosphorus application on the productivity and water use efficiency of greengram. The levels of phosphorus application were kept as 0, 30, 60 and 90 kg P_2O_5 ha^{-1}. It was recorded that the maximum yield of grains and the highest water use efficiency was recorded for the phosphorus application level of 60 kg P_2O_5 ha^{-1}.

Parihar *et al*. (2017) studied the various nutrient treatments *viz*., unfertilized (control), Farmer's fertilizer practice, recommended dose of fertilizer (Ad-hoc) and Nutrient Expert decision support tool-based fertilizer application (SSNM) in Maize-wheat-mungbean crop sequence. Among the treatments, substantial improvement in WUE was found in SSNM and ad-hoc nutrient management treatments, eventually higher yields of the cropping system. It was recommended that sufficient and balanced nutrient supply resulted in higher WUE in these treatments.

On the sandy-clay-loam soils of Afghanistan, Jalali and Choudhary (2018) conducted an experiment on summer mungbean to evaluate the effect of variousnitrogen levels (0,10, 20, 30, 40, 50, 60 kg N ha^{-1}) on the water use efficiency. Maximum value of water use efficiency was recorded when the nitrogen was applied at the rate of 30 kg Nitrogen per hectare (33.47 kg N ha^{-1} as optimum dose calculated as site specific) compared to all the treatments.

Hari Ram *et al*. (2018) reported the effect of nutrient application on the enhancement of water use efficiency onthree nutrient treatments on the loamy sand soils of Ludhiana, on *kharif* mungbean. It was found that the maximum yield and water use efficiency was found at nutrient treatment 12.5 kg N + 40 kg P_2O_5than 6.25 kg N+ 20 kg P_2O_5 ha^{-1} and was found at par with 9.38 kg N+24 kg P_2O_5 ha^{-1}.

Hamim and Choudhary (2019) conducted a field study on the sandy clay soils of Afghanistan with seven levels of K_2O application. They enlightened that the variation in the potassium application results in the influence on the efficiency of water use in *kharif* mungbean. The treatment K_2O application @ 80 kg/ha resulted in higher water use efficiency (8.46 kg ha^{-1} mm^{-1}) than control (5.93 kg ha^{-1} mm^{-1}), 20 (6.76 ha^{-1} mm^{-1}), 40(7.41 ha^{-1} mm^{-1}), 60 (8.15ha^{-1} mm^{-1}) and 100 kg K_2O (8.15 ha^{-1} mm^{-1}). The increased value of WUE might have been due to effectual turgor regulation, osmotic adjustment and enhanced plant water relationships with potassium fertilizer application (Kabir *et al*., 2004).

Inoculation

The inoculation of the crops results in the marked improvement in the consumptive use of water and water use efficiency. Enhancement in nutrient uptake by VAM fungi during water discrepancy phase is suggested mechanism for improving drought resistance (Nye and Tinker,1977; Nelson and Safir,1982). The effect of seed treatment with VAM was adjudged by Singh *et al* (2006) and reported that inoculation by VAM yielded maximum yield and maximum water use efficiency (45.69 kg ha^{-1} mm^{-1}) than control (44.93 ha^{-1} mm^{-1}). Habibzdeh *et al*. (2013) reported that the highest value of ecosystem water use efficiency of mungbean was recorded for the plants inoculated by the AM-fungi as compared to the non-mycorrhizal plants.

Mulching

Mulching refers to as a barrier between the soil environment and the atmosphere. It acts as a best option for conserving the moisture of the soil, moderation of the soil temperature, helps in the modification of the microclimatic conditions, helps in the improvement of the soil physical, chemical and biological properties of the soil, suppresses the weed growth in the crop field and keep a check on the erosion of the soil by air and water (Kaur and Bons, 2017). Singh *et al*., (1981) reported the effect of mulch application on the water use efficiency of spring mungbean on the sandy loam soils of IARI, New Delhi. The application of straw mulch resulted in the highest water use efficiency for consecutively two years as compared to the soil mulch application and the no mulch treatment.

Mohammad *et al*. (2010) reported that the water use efficiency of the grain as well as the straw is influenced by the retention of the crop residue on the field. The highest water use efficiency was recorded with the no tillage and crop residue retention treatment than without crop residues. Bhardwaj (2013) reported that application of 3-5 t ha^{-1} organic matter stimulates microflora of soil, increase soil biological activity and participates in nutrient cycle.

In an experimental study, Ji *et al*., (2011) formulated that the application of plastic film mulch on the ridges, plastic film mulch on 'W' ridges and mulch on the whole plot resulted in the improvement of the water use efficiency by 12.59%, 104.90% and 100.27% respectively. Among all, plastic film mulch on the ridge was the most effective treatment for improvement of the water use efficiency and the grain yield. Kaur *et al*. (2021) reported that application of 6 tonnes ha-1 along with 30% depletion from the available soil moisture results in saving 1 irrigation from the recommended irrigation schedule by Punjab Agricultural University, Ludhiana. Bunna *et al*. (2011) carried out a research experiment in the rice field of Cambodia to study the effect of straw mulch on the yield and water use efficiency of mungbean of *rabi* season. It was reported that the highest water use efficiency was recorded when the straw mulch was applied at the rate of 2 t/ha.

Sharma and Bhardwaj (2017) reviewed that application of mulch paper results in reduction in application of herbicides and chemical fertilizers, controls weed as well as maintains the temperature of land. A study was conducted by Hari Ram *et al*., (2016b) to evaluate the effect of straw mulching on the water use efficiency of the summer mungbean. From the three levels of mulch (no mulch, mulch application at time of sowing and mulching at 25 days after crop sowing), the mulch application at 25 DAS resulted in higher yield and maximum water use efficiency.Similarly, Sekhon *et al*. (2020) reported maximum water expense efficiency under plastic mulch followed by rice straw mulch and no mulch treatment being lowest in potato crop.

Spacing

The effect of planting density or in easy terms the effect of the plant spacing on the efficiency of water use in summer greengram was studied by the Chaudhary *et al*., (2014) on the loamy sand soils of Sardar krushinagar. It was conveyed that the maximum water use efficiency was recorded when the crop was sown under the plant spacing of 30 $\times$ 10 cm than 22.5 $\times$ 10 cm and 45 $\times$ 10 cm. They concluded that the wide spacing of the crop results in the reduction of the water use efficiency. The highest seed yield was also resulted from the plant spacing of 30 $\times$ 10 cm.

Weed control

The weed control is the most important factor for management which affects the water use efficiency. Weeds compete for nutrients, space as well as water. The moisture need of the weed plants is higher than the crop plants.

In a study on summer mungbean by Hari Ram *et al*., (2016b) found that the treatment of Pendimethalin @ 0.75 kg/ha proved effective in enhancing the grain yield and water use efficiency which was significantly higher than the unweeded treatment plot kept as a control.

CONCLUSION

The overall review details out that the agronomic interventions like the plant population, sowing date, spacing, irrigation, fertilization, mulching, weed control, *etc*. all have positive impact on improving the water use efficiency of the greengram. Consequently, this improved water use efficiency unswervingly results in the increased productivity of the crop and overall benefit and profit of the farmers.

Conflict of interest: None.

REFERENCES

Ahmad, A.M., Selim, M.A., Alderfasi, A. and Afzal, M. (2015). Effect of Drought Stress on Mungbean (*Vigna radiate* L.) Under Arid Climatic Conditions of Saudi Arabia. In: Ecosysten and Sustainable Development. [Garcia, J.L.M. and Brebbia, C.A. (eds.)]. WIT Press, Southampton, UK. 185-193.

Asaduzzaman, M., Karim, F.M., Ullah, M.J. and Hasanuzzaman, M. (2008). Response of mungbean (*Vigna radiata* L). to nitrogen and irrigation management. American-Eurasian Journal of Scientific Research. 3(1): 40-43.

Ati, A.S., Tahaand, W.A.A., Nasrall, A. (2016). Role of Potash Fertilization in Reduction of Water Stress in Mungbean (*Vigna radiate* L), Water use Efficiency and Yield. In The 2nd Scientific Agricultural Conference. 616.

Lal Bhardwaj, R. (2013). Effect of mulching on crop production under rainfed condition-a review. Agricultural Reviews. 34(3).

Bons, H.K., Rattanpal, H.S. and Brar, A.S. (2018). Influence of different mulches on growth and productivity of kinnow mandarin. Agricultural Research Journal. 55(4): 765-767.

Bunna, S., Sinath, P., Makara, O., Mitchell, J. and Fukai, S. (2011). Effects of straw mulch on moongbean yield in rice fields with strongly compacted soils. Field Crops Research. 124: 295-301.

Buttar, G.S. (2014). Modern Techniques for Enhancing Water Productivity in Field Crops. Paper published in National Conference: Agricultural Diversification for Sustainable Livelihood and Environmental Security pp: 39-43.

Buttar, G.S. and Kaur, A. (2010). Performance of different genotypes of clusterbean (*Cyamopsis tetragonoloba*) under various sowing dates. Crop Research (Hisar): 39(1/2/3) 62-64.

Chaudhary, A.N., Vihol, K.J. and Mor, V.B. (2014). Water Use Efficiency, Yield, Available Nutrient and Economics of greengram (*Vigna radiata* (L.) Wilczek) as influenced by plant density and irrigation management. Bioscience Trends. 7(22): 3761-3764.

Ehsan, Q., Rana, D.S. and Choudhary, A.K. (2017). Productivity and resource-use efficiency of greengram (*Vigna radiata*) as influenced by sowing methods and phosphorus levels under semi-arid conditions of Afghanistan. Indian Journal Agronomy. 62(3): 367-370.

El-Nakhlawy, F.S., Ismail, S.M. and Basahi, J.M. (2018). Optimizing mungbean productivity and irrigation water use efficiency through the use of low water-consumption during plant growth stages. Legume Research-An International Journal. 41(1): 108-113.

Goswami, P., Singh, R.S. and Bharati, V.R. (2017). Enhancing crop production by enhancing water use efficiency -A review. Agriculture for Sustainable Development. 5(1): 111-117.

Habibzadeh, Y., Pirzad, A., Zardashti, M.R., Jalilian, J. and Eini, O. (2013). Effects of Arbuscular Mycorrhizal Fungi on Seed and Protein Yield under Water Deficit Stress in Mung Bean. Agronomy Journal. 105(1): 79-84.

Hamim, H. and Choudhary, A.K. (2019). Influence of varying potassium levels on yield, water productivity, profitability and resource-use efficiency in *kharif* mungbean (*Vigna radiata*) under semi-arid conditions of Afghanistan. Indian Journal of Agricultural Sciences. 89(3): 551-555.

Hari Ram, Singh, G. and Aggarwal, N. (2016b). Effect of irrigation, straw mulching and weed control on growth, water use efficiency and productivity of summer moongbean. Legume Research. 39: 284-288.

Hari Ram, Singh, G., Aggarwal, N. and Sekhon, H.S. (2018). Effect of sowing methods, nutrients and seed rate on mungbean [*Vigna radiata* (L.) Wilczek] growth, productivity and water-use efficiency. Journal Applied Natural Sciences. 10(1): 190-195.

Hari Ram, Aggarwal, N., Singh, G. and Singh, S. (2016a). Heat and water-use efficiency in summer mungbean [*Vigna radiata* (L.) Wilczek] under different thermal and moisture regimes. Journal of Agrometeorology. 196-200.

Idnani, L.K. and Singh, R.J. (2008). Effect of irrigation regimes, planting and irrigation methods and arbuscular mycorrhizae on productivity, nutrient uptake and water use in summer greengram (*Vigna radiate* var *radiata*). Indian Journal of Agricultural Sciences. 78(1): 53.

Israelson, O.W. (1932). Irrigation Principles and Practices. Wiley and Sons, New York. Pp 411.

Jalali, M.N. and Choudhary, A.K. (2018). Influence of varying nitrogen levels on productivity, resource-use efficiency and profitability of summer mungbean (*Vigna radiate* L. wilczek) in Kandahar province of Afghanistan. Annals of Agricultural Research. 39(2): 180-186.

Ji, X.L., Yue, P.P., Zhan, J., Liu, J.H., Lei, J.Y. and Zhang, X. (2011). Effects of different mulching methods on effective culture technique of mung bean. Research of Soil and Water Conservation. 3.

Jiang, S., Gao, X., Liang, J., Wang, P., Gao, J., Qu, Y. and Feng, B. (2012). Effect of different furrow and mulched ridge on water moisture conversation and water saving of spring moong bean planted farmland. Journal of Agricultural Sciences. 4: 132.

Kabir, M.E., Karim, M.A. and Azad, M.A.K. (2004). Effect of potassium on salinity tolerance of mungbean (*Vigna radiata* L.). Journal Biological Sciences. 4(2): 103-110.

Kaur, A. and Singh, V.P. (2006). Effect of planting methods, mulching and weed control on nutrient content and its uptake by pearlmillet under rainfed conditions. Crop Research. 31(3): 362-365.

Kaur, A., Sidhu, A.S., Sekhon, K.S., Thaman, S. and Buttar, G.S. (2017a). Economically viable cropping sequence for diversification in south-western region of Punjab. Journal of Soils Crops. 27(2): 12-16.

Kaur, A., Buttar, G.S., Sekhon, K.S. and Sidhu, A.S. (2016). Response of Indian Mustard (*Brassica juncea* L.) to different doses of sulphur and quality of water and its residual effect on growth and yield of succeeding moong bean crop. Crop Research. 51(4, 5 and 6): 113-116.

Kaur, A., Sekhon, K.S., Thaman, S., Sidhu, A.S. and Buttar, G.S. (2018). Evaluation of Mustard (*Brassica juncea*) and barley (*Hordeum vulgare*) based cropping sequence under variable irrigation supplies. Indian Journal of Agricultural Sciences. 88(7): 1129-1136.

Kaur, A., Thaman, S., Sidhu, A.S., Sekhon, K.S. and Buttar, G.S. (2017b). Effect of variable irrigation supply based diversification of *Bt* cotton (*Gossypium hirsutum*) - wheat (*Triticuma estivum*) system on productivity, profitability, soil fertility and water expense efficiency. Indian Journal of Agronomy. 62(4): 431-437.

Kaur, J. and Bons, H.K. (2017). Mulching: A viable option to increase productivity of field and fruit crops. Journal of Applied Natural Sciences. 9(2): 974-982.

Kaur, L., Kaur, A. and Brar, A.S. (2021). Water use efficiency of green gram (*Vigna radiata* L.) impacted by paddy straw mulch and irrigation regimes in north-western India. Agricultural Water Management. 258(1): 107184.

Kaur, N. (2014). Growth, yield and water productivity of bed-planted summer moong in relation to irrigation regimes.M.Sc. thesis, Punjab Agricultural University, Ludhiana.

Kumar, A. and Rana, K.S. (2007). Performance of pigeonpea + greengram intercropping system as influenced by moisture conservation practice and fertility level under rainfed conditions. Indian Journal Agronomy. 52(1): 31-35.

Kumar, P.R., Mali, S.S., Singh, A.K. and Bhatt, B.P. (2021). Impact of irrigation methods, irrigation scheduling and mulching on seed yield and water productivity of chickpea (*Cicer arietinum*). Legume Research-An International Journal. 44(10): 1247-1253.

Kumar, Y., Uttam, S.K. and Singh, R. (2016). Effect of planting techniques and irrigation schedules on yield, root development, water use efficiency and economics of summer greengram. Research of Environmental Life Sciences. 9(6): 721-724.

Mandai, S., Biswal, K.C. and Jana, P.K. (2005). Yield, economics, nutrient uptake and consumptive use of water by summer greengram (*Vigna radiata* L.) as influenced by irrigation and phosphorus application. Legume Research. 28(2): 131-133.

Mohammad, W., Shehzadi, S., Shah, S.M. and Shah, Z. (2010). Effect of tillage and crop residues management on mungbean [*Vigna radiata* (L.) Wilczek] crop yield, nitrogen fixation and water use efficiency in rainfed areas. Pakistan Journal of Botany. 42: 1781-1789.

Nelsen, C.E. and Safir, G.R. (1982). The water relations of well-watered mycorrhizal and non-mycorrhizal onion plants. Journal of American Society Horticultural Sciences. 107: 271-274.

Noorzai, A.U., Choudhary, A.K., Bana, R.S. and Prasad, R. (2017). Influence of summer mungbean genotypes on grain yield and resource-use efficiency in Kandahar province of Afghanistan. Annals of Agricultural Research. 38(2): 194-199.

Nye, P.H. and Tinke, P.B. (1977). Solute movement in the soil-root system. University of California Press, Berkeley.

Pannu, R.K. and Singh, D.P. (1993). Effect of irrigation on water use, water-use efficiency, growth and yield of mungbean. Field Crops Research. 31(1 and 2): 87-100.

Parihar, C.M., Jat, S.L., Singh, A.K., Ghosh, A., Rathore, N.S., Kumar, B., Majumdar, K., Satyanarayana T., Jat, M.L., Saharawat, Y.S., Kuri, Saveipune D. (2017). Effects of precision conservation agriculture in a maize-wheat-mungbean rotation on crop yield, water-use and radiation conversion under a semiarid agro-ecosystem. Agricultural Water Management. 192: 306-319.

Phogat, B.S., Singh, D.P. and Singh, P. (1984). Responses of cowpea [*Vigna unguiculata* (L.) Walp.] andmung bean [*Vigna radiata* (L.) Wilczek] to irrigation. Irrigation Science. 5(1): 47-60.

Praharaj, C.S., Singh, U., Singh, S.S., Kumar, N. and Jat, R.L. (2016). Crop growth, productivity, water use and economics in mungbean and urdbean as influenced by precision tillage and sprinkler irrigation scheduling. Journal of Food Legumes. 29(2): 116-122.

Ranawake, A.L., Dahanayaka, N., Amarasingha, U.G.S, Rodrigo, W.D.R.G., Rodrigo, U.T.D. (2011). Effect of water stress on growth and yield of mung bean (*Vigna radiate* L). Tropical Agricultural Research and Extension. 14(4).

Roy, S., Barman, M., Puste, A.M., Gunri, S.K. and Jana, K. (2015). Growth, yield, water use efficiency and competitive functions of intercropping system of maize (*Zea mays* L.) and mungbean (*Vigna radiata* L.) as influenced by irrigation. SAARC Journal of Agriculture. 13(2): 94-107.

Sekhon, K.S., Kaur, A., Thaman, S., Sidhu, A.S., Garg, N., Choudhary, O.P., Buttar, G.S. and Chawla, N. (2020). Irrigation water quality andmulching effects on tuber yield and soil properties in potato (*Solanum tuberosum* L.) under semi-arid conditions of Indian Punjab. Field Crops Research. 247 (107544).

Sharma, B., Molden, D. and Cook, S. (2015). Water use efficiency in agriculture: Measurement, current situation and trends. Managing water and fertilizer for sustainable agricultural intensification. 39-64 (No. 612-2016-40604).

Sharma, R. and Bhardwaj, S. (2017). Effect of mulching on soil and water conservation- A review. Agricultural Reviews. 38(4).

Singh, A.K., Bhatt, B.P., Sundaram, P.K., Gupta, A.K. and Singh, D. (2013). Plant geometry to optimize growth and productivity of faba bean (*Vicia faba* L.) and soil fertility. Journal of Environmental Biology. 34(1): 117-122.

Singh, A.K. and Kumar, P. (2009). Nutrient management in rainfed dryland agro ecosystem in the impending climate change scenario. Agricultural Situation in India. 66(5): 265-270.

Singh, A.K., Manibhushan, C.N. and Bharati, R.C. (2008). Suitable crop varieties for limited irrigated conditions in different agroclimatic zones of India. International Journal of Tropical Agriculture 26(3-4): 491-496.

Singh, A.K., Bhatt, B.P., Sundaram, P.K., Chandra, N., Bharati, R.C. and Patel, S.K. (2012a). Faba bean (*Vicia faba* L.) phenology and performance in response to its seed size class and planting depth. International Journal of Agricultural and Statistical Sciences. 8(1): 97-109.

Singh, A.K., Sangle, U.R. and Bhatt, B.P. (2012b). Mitigation of imminent climate change and enhancement of agricultural system productivity through efficient carbon sequestration and improved production technologies. Indian Farming. 61(10): 5-9.

Singh, A.K., Singh, A.K., Jaiswal, A., Singh, A., Upadhyay, P.K. and Choudhary, S.K. (2014c). Effect of irrigations and phosphorus fertilization on productivity, water use efficiency and soil health of Summermungbean (*Vigna radiata* L.). The Ecoscan. 8(1and2): 185-91.

Singh, A., Ahlawat, I.P.S. and Saraf, C.S. (1981). Response of spring mung [*Vigna radiata* (L.) Wilczek] bean to irrigation and anti-transpirants with and without mulching. Annals arid zone. 20(1): 28-34.

Singh, D., Agarawal, K.R.L. and Ahuja, K.N. (1998). Response of wheat varieties to different seeding dates for agro climatic conditions of Agra region. Annals of Agricultural Research. 19(4): 496-498.

Singh, I., Beg, M.K.A., Akhter, S., Qayoom, S., Lone, B., Singh, A.P. and Singh, P. (2014a). Efficient techniques to increase water use efficiency under rainfed eco-systems. Journal of Agriculture Research. 1(4).

Singh, R.J., Idnani, L. and Rai, R. (2006). Grain yield, water use efficiency, economics and soil moisture extraction pattern of summer greengram (*Vigna radiata* var. *radiata*) as influenced by planting and irrigation methods; Irrigation schedules and vam inoculation. Annals of Agricultural Research. 27(3).

Singh, S.S., Singh, A.K. and Sundaram, P.K. (2014b). Agro-technological options for upscaling agricultural productivity in eastern Indo-gangetic plains under impending climate change situations: A review. Journal of Agricultural Research. 1(2): 55-65.

Soni, K.C. and Gupta, S.C. (1999). Effect of irrigation schedule and phosphorus on yield, quality and water-use efficiency of summer mungbean (*Phaseolus radiata*). Indian Journal of Agronomy. 44(1): 130-133.

Uddin, S. and Parvin, S. (2013). Yield performance of mungbean (*Vigna radiata* L.) as influenced by irrigation. International Journal of Agronomy and Plant Production. 4(5): 3659-3667.

Yadav, S. and Singh, B.N. (2014). Effect of irrigation schedules and planting methods on growth, productivity and WUE of green gram (*Phaseolus radiata* L.) under rice-wheat-green gram cropping system. Plant Archives. 14: 211-213.