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Effect of drip fertigation on pigeonpea [*Cajanus cajan* (L.) Millsp] – A review

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ABSTRACT

Food legumes are important source of protein in the diets of a large section of vegetarian population in the developing countries in general and India in particular. Even though India has the largest area under pulses in the world, the average productivity is relatively low and the production is not adequate to meet the demand. For increasing the productivity of the pulses key inputs viz., water, seeds and nutrients need to be applied in the right quantity to enhance the production. The water use efficiency is increased through micro irrigation in the form of drips and sprinklers. Drip irrigation can be considered as an efficient irrigation system since it causes wetting of the soil only and maintain optimum moisture content in the root zone. It also offers several water management advantages like timely application of water and water supply. Micro irrigation provides many unique agronomic, water and energy conservation benefits that address many of the challenges facing irrigated agriculture, now and in the future.

Key words: Drip irrigation, Fertigation, Growth attributes, Pigeonpea, Water use efficiency, Yield.

Enhancing sustainable food production would require proper and judicious use of land, water and fertilizer resources. Among the agronomic practices, nutrient and water management play a vital role in determining the yield and quality of the produce. This can be achieved through application of adequate quantity of the available water and fertilizers economically. Due to uneven distribution of rainfall, drought during the critical crop growth stage, improper water and nutrient management practices drastically reduces the production of pulses in our country. Drip irrigation is one such hi-tech method receiving wider acceptance and adoption, particularly in areas of water scarcity. Fertigation is a recent innovative method, by which fertilizers are applied along with irrigation water through drip system to get higher fertilizer use efficiency besides enhancing the crop yields. The system of pulses intensification is a new concept for augmenting pulses productivity by growing pulses under irrigated condition along with drip fertigation. This would enable to reduce the gap between supply and demand.

Water requirement of pigeonpea: Water is an essential input to achieve desired growth and yield of any crop. Water requirement of a crop is the quantity of water needed for normal growth, development and yield and may be supplied through precipitation or by irrigation or by both. On an average, pigeonpea uses around 200-250 mm water to produce about one tonne grain ha^{-1}. To get the maximum production of pigeonpea, the irrigation could be scheduled by adopting IW/CPE ratio of 0.30 (Gajera and Ahlawat, 2006). Pramod (2007) reported that seed yield of pigeonpea (16.51 q ha^{-1}) with two protective irrigations was significantly higher than one protective irrigation (14.33 q ha^{-1}) and control (10.96 q ha^{-1}) under Raichur condition. Duraisamy and Manickasundaram (2008) reported that the perennial pigeonpea (BSR 1) with 0.45 IW/CPE irrigation schedule showed the highest water use efficiency of 1.05 kg ha^{-1} mm^{-1} as compared to other treatments. Mula *et al*. (2010) observed that irrigation at every 14 days from flower initiation to pod development stage of pigeonpea was optimum for producing ample quantity seeds of ICPA 2043 in alfisols at ICRISAT, Patancheru, India. Thanki and Solanki (2010) recorded the highest seed (1429 kg ha^{-1}) and stalk yield (3921 kg ha^{-1}) in pigeonpea by scheduling irrigation at IW/CPE ratio of 0.9.

Need for drip fertigation: Agricultural sector is the largest consumer of water. Adoption of micro irrigation may help in saving significant amounts of water and increase the quality and quantity of produce. All these emphasize the need for water conservation and improvement in water-use efficiency to achieve 'more crop per drop'of water. Fertigation is the application of fertilizers through irrigation water. By definition, fertigation is the precise application of water soluble fertilizers through sprinkler and drip irrigation systems. When required fertilizers were applied along with water through drip irrigation system, there was considerable saving of fertilizers besides increased yield and saving of water compared to surface method of irrigation. It helps to achieve higher fertilizer and water use efficiency. The benefits of fertigation have been examined in several studiesially in commercial crops. Drip fertigation may reduce the risk of crop damage in many crops due to high water

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table coupled with heavy rains. Fertigation allows nutrient placement directly into root zone during critical periods of nutrient demand. Drip fertigation provides an efficient method of fertilizer delivery and if properly managed, reduce overall fertilizer application rate and minimize the adverse environmental impact.

Advantages

- Nutrients can be applied at any time during the season and according to crop requirements.
- Placement of mobile nutrients such as nitrogen can be regulated in the soil profile by the amount of water applied.
- Applied nutrients are readily available for rapid crop uptake.
- Nutrients are applied uniformly over the field.
- Crop damage during fertilizer application is minimized.

Nutrient supply to crops through fertigation is determined by their concentration in irrigation water, nutrient uptake by the plant, rate of evapotranspiration and reactions such as precipitation or fixation by the growth medium. Optimization of nutrient and water supply for maximizing crop yield and quality and minimizing leaching below the rooting volume are achieved by managing fertilizer concentrations in measured quantities of irrigation water, according to crop requirements. Fertigation enhanced the overall root activity, improved the mobility of nutritive elements and their uptake, as well as reducing the contamination of surface and ground water.

Drip irrigation has gained wide spread popularity as an efficient method for fertigation because both time and rate of nutrients can be controlled to meet the requirements of a crop at each physiological growth stage. Drip fertigation enables accurate adjustment of water and nutrient supply to meet the actual crop requirements. This method of irrigation decreases leaching and volatilization losses, improves the nitrogen utilization efficiency and minimizes ground water contamination. In addition, applying nitrogenous fertilizer with the irrigation water is a more convenient and less expensive method compared to the traditional direct soil application methods. Trickle fertigation permits application of nutrients directly at the site of high concentration of active roots. A properly designed drip fertigation system delivers water and nutrients at a rate, duration and frequency, so as to maximize crop water and nutrient uptake, while minimizing leaching of nutrients and chemicals from the root zone of agricultural fields (Gardenas *et al*., 2005). The main advantage of fertigation is that because the nutrients are applied in solution form near the root zone, they are immediately available to the plants. Additionally, the quantity of nutrients delivered can be easily adjusted to match the crop needs. The ability of application of nutrients in a precise manner to match the crop nutrient requirement in a localized area helps in maximizing the nutrient uptake efficiency. Fertigation allows nutrient placement directly into root zone of crop during critical periods of nutrient demand. Drip fertigation provides an efficient method of fertilizer delivery and if properly managed, reduce overall fertilizer application rate and minimize the adverse environmental impact.

Nutrient requirement for pulses: Nitrogen, phosphorus and potassium are the three major and primary nutrients required for the crop growth and productivity. Small amount of nitrogen is very important during early phase for seedling vigor. Phosphorus is necessary for energy storage and transfer and is essential for vigorous growth and seed development. It enhances crop maturity and quality, especially in grain crops. Potassium maintains water balance and therefore stalk strength. In addition, potassium promotes energy generation which is required for translocation of nutrients in the plant, nitrogen uptake and protein synthesis. Crops that are potassium deficient result in low total nitrogen uptake, yield and protein. Legumes fix their own nitrogen if proper inoculants and sufficient amounts of phosphorus, potassium, sulphur and micronutrients are present. Maximum nitrogen uptake occurs during branching and early bud formation (Malhi *et al*., 2007). Therefore during early growing period, availability of phosphorus and potassium is critical not only for direct incorporation into plant biomass but to ensure early nitrogen fixation. Fertile soils that produce high yields of other crops also produce high yields of pigeonpea. Total nutrient uptake by pigeonpea depends on yield obtained, which will vary with season, variety, soil, nutrient status and cultural practices. Pigeonpea takes up relatively small amounts of nutrients early in the season, but as it grows and develops, the daily rate of nutrient uptake increases and it requires an adequate supply of nutrients at each developmental stage for optimum growth. High yielding long duration pigeonpea removes substantial nutrients from the soil, and this should be taken into account in an overall nutrient management plan.

Nitrogen requirement: Application of adequate supply of nitrogen is usually associated with increased yield and protein content of pigeonpea. Pulses can meet their own nitrogen requirement by symbiotic fixation of atmospheric nitrogen. However, a starter dose of nitrogen and adequate phosphorus are considered as essential for obtaining optimum yield. Kumar Rao *et al*. (1981) stated that pigeonpea responded well to the application of 20 kg N ha^{-1} as basal dose resulting in increased plant height upto 65 days. In pigeonpea, higher yield was obtained when nitrogen was applied at 120 kg ha^{-1}. Application of nitrogen as urea source at 20 and 40 kg ha^{-1} significantly increased the shoot, root and total plant dry matter production (Durante and Carpne, 1981). Singh and Bahadur (1990) opined that an addition of 45 kg N ha^{-1} promoted maximum vegetative growth and produced highest yield of green pods. Balanced supply of nitrogenous fertilizer

not only improves crop yield and nutrient uptake but also nodulation in pigeonpea. Sheelavantar and Singh (1992) observed significant increase in Leaf area index, Leaf area duration and dry matter production with increasing level of nitrogen upto 50 kg ha^{-1} over control. Number of branches $plant^{-1}$ and number of leaves $plant^{-1}$ also increased significantly with increasing level of nitrogen upto 50 kg ha^{-1}. Significant improvement in plant height was observed with increasing levels of N at 60 days after sowing (Chittapur *et al*., 1994). Kale *et al*. (1997) found that 75 kg N ha^{-1} was the optimum level for getting highest yield of quality pods. Application of 30 kg N ha^{-1} produced significantly higher yield through higher number of pods in pigeonpea. Inoculation of rhizobium significantly increased the number of nodules per plant and grain yield by application of 20 kg N ha^{-1}. Split application of 50 per cent N as basal + 50 per cent N at branching proved to be the most effective for realizing higher yield in french bean (Ghosal and Bahl, 2000).

Phosphorus requirement: Phosphorus is one of the most important nutrients needed by legumes in adequate amount but their response to applied fertilizer is many times uncertain and poor. The phosphorus requirement is in the range of 0.3 to 0.5 per cent of dry weight during the vegetative stage of the crop growth. Plants obtain their phosphorus in soluble ionic forms (HPO_4^- and $H_2PO_4^-$). The deficiency of phosphorus to the plant is due to its fixation in soil. Based on the study, it is suggested that phosphorus plays an important role in nitrogen fixation through an effective translocation of phosphorus to the leaf. Phosphorus fertilizer is generally required to achieve sufficient plant phosphorus concentrations in drip irrigation system compared with other application methods (Rubiez *et al*., 1991). Phosphorous application through drip irrigation is not commonly recommended, mainly because of the possibility of precipitation of phosphates and the low mobility of phosphates (Mikkelsen, 1989). Phosphorous is highly immobile in soils and is often a limiting nutrient. Phosphorus deficient plants suffer from reduced leaf expansion, reduced surface size and reduced number of leaves. Respiration and photosynthesis are both reduced in phosphorus deficient plants. Stress from phosphorus deficiency at early growth stage has considerable negative influence on crop production (Grant *et al.,* 2001). Among all the elements required by a plant, phosphorus is one of the most important nutrients for crop production and emphasis is to be given on the efficient use of P fertilizer for sustainable crop production (Ryan, 2002). Crop response to P fertilizer depends on genetic and physiological characteristics of the plant that helps in efficient P uptake and utilization or this will be facilitated by the development of more P-efficient crop cultivars that will yield more per unit of phosphorus applied. Pigeonpea is a highly exhaustive pulse crop and requires higher amount of P nutrition for optimum production (Kumar and Kushwaha, 2006). Application of phosphorus to legumes improves the seed yield considerably. Kargbo *et al.* (1991) reported that increase in P application frequency resulted in greater P uptake and suggested that the higher P application frequency caused greater mass flow and greater mixing action, leading to the breakdown of regions of immobile P. The P requirement of crops is very high during initial stages of plant growth. An adequate P supply from soil and fertilizer is, therefore, necessary. Jain and Kushwaha (1999) found that with increase in P levels from 30 to 60 kg ha^{-1}, the grain yield and protein content were found to increase. They also observed that biofertilizer (Rhizobium + PSB) inoculation with 60 kg P_2O_5 ha^{-1} gave the highest seed yield. Adhikary and Sarkar (2000) reported that the seed yield of pigeonpea increased significantly with increasing levels of P upto 60 kg P_2O_5 ha^{-1}.

Potassium requirement: Potassium is known to play a vital role in osmoregulation and activation of several enzymes. Besides this, it helps the plant to adapt under terminal moisture stress/abiotic stresses mostly experienced during reproductive stage. Potassium is involved in many physiological processes which influence crop quality, it activates more than 60 enzymes systems, aids photosynthesis, favours high energy status, regulates opening of leaf stomata, maintains cell turgor, promotes water uptake, regulates nutrient translocation, favours carbohydrate transport and hence enhance protein and starch synthesis (Brar and Imas, 2010). Potassium is also easily soluble in water and applied through drip irrigation. Regular application of nitrogen and potassium with a high frequency drip irrigation system has improved the nutrient uptake efficiency of sweet corn in sandy soils and reduced leaching loss. In alluvial soils, the response of pigeonpea (cv Type 21) to potassium was studied at different irrigation levels. With two or three irrigations, optimum yield was obtained at 50 kg ha^{-1} potassium under rainfed conditions and 75 kg ha^{-1} potassium proved to be the best under rainfed condition (Afridi *et al*., 1990). Hedge and Srinivas (1990) reported that highest K uptake was recorded at -45 kPa and -65 kPa than at -85 kPa in French bean. When comparing yield attributes of ten crops, pigeonpea recorded the maximum apparent root depth of 115 cm, mean root extension 11.0 mm d^{-1}, mean rate of water extraction 2.86 mm d^{-1}, total transpiration 229 mm, transpiration efficiency for assimilation 2.64 g mm^{-1}, harvest index on an assimilation basis 0.39 and economic yield per glucose equivalent 0.75 gg^{-1} (Pandey *et al*., 1987). Higher potassium content in leaf was obtained under drip fertigation (Obreza and Vavrina, 1995). Anilkumar (2001) reported that potassium uptake was significantly higher (105.14 kg ha^{-1}) with 100 per cent water needed at 0.8 IW/CPE ratio than 75 per cent of water. Like nitrogen, potassium is particularly suited to fertigation. It is taken up in large quantities (second to nitrogen) and is particularly important late in the growing season in flower formation to pod initiation. Potassium is subject to fixation in certain soils and leaching in sandy soils. Some soils cannot supply potassium fast enough to meet crop

demands during periods of rapid growth. Crop utilization of applied nutrients and produce quality are often enhanced when potassium is applied through fertigation. Trickle irrigated potassium moves both laterally and downward, allowing more uniform spreading of potassium in the wetted volume of soil. Potassium is less mobile than nitrate and distribution in the wetted volume may be more uniform due to interaction with soil binding sites. Potassium sulphate applied through micro irrigation system resulted in quicker and higher potassium uptake in leaf compared to trench applied potassium. Potassium fertilizers, when added to irrigation water, do not generally cause any adverse chemical reactions that plug irrigation pipes and emitters. But they may well cause precipitation of insoluble salts if mixed with other fertilizers (Rolston *et al.,* 1986). Higher potassium content in leaf was obtained under fertigation (Obreza and Vavrina, 1995). Anilkumar (2001) reported that potassium uptake was significantly higher (105.14 kg ha^{-1}) with 100 per cent water at 0.8 IW/CPE ratio than 75 per cent of water. Tumbare and Nikam (2004) stated that application of recommended dose of fertilizer at every irrigation (2 days interval) upto 105 days recorded significantly higher uptake of potassium (99.1 kg ha^{-1}) by chilli than surface irrigation (44.6 kg ha^{-1}). Grain yield of pigeonpea was increased significantly with the application of potassium upto 60 kg K_2O ha^{-1} by 29 per cent and the agronomic efficiency of potash applied to pigeonpea was 6.6 kg kg^{-1} K_2O (Tiwari *et al*., 2012).

Effect of drip fertigation on growth and yield attributes: Selva Rani (2009) reported that drip irrigated maize crop at 100 per cent PE, once in three days had higher values of growth parameters like plant height and stem girth as compared to irrigation regime of 75 per cent PE. Among the fertigation levels, drip fertigation at 150 per cent RDF with P as water soluble fertilizer (17:44:0 grade) enhanced growth parameters favourably over other levels. Anitta Fanish (2010) revealed that drip fertigation with 100 per cent RDF with 50 per cent P and K as water soluble fertilizer (WSF) recorded significantly higher growth parameters like plant height, leaf area index, dry matter production, rooting depth, root volume and root biomass of maize. She also reported that higher Crop Growth Rate (CGR) of maize was observed under drip fertigation at 100 per cent RDF (50 per cent P and K as WSF), which was comparable with fertigation with 150 per cent RDF. Mahalakshmi *et al.* (2011) reported that pigeonpea under drip irrigation with0.8 Epan throughout the crop period recorded higher plant height (61.6 cm), LAI (2.04) and total dry matter production (3731 kg ha^{-1}) at harvest.

Abdullah Oktem (2008) reported that the highest fresh ear yields (14.76 and 14.17 t ha^{-1}) were obtained at 100 per cent Epan, whereas minimum fresh ear yields (9.15 and 8.84 t ha^{-1}) were found at 70 per cent of Epan in 1998 and 1999, respectively. Despite the reduction of fresh ear yield, the number of marketable ears at 10 per cent water deficiency (90 % Epan) was still high and acceptable for sweet corn production in the Harran Plain of Turkey. Ramulu *et al.* (2010) reported that grain yield was significantly higher (7.46 t ha^{-1}) in fertigation scheduled at 1.0 Epan and 100 per cent RDF with water soluble fertilizers (MAP, urea, KNO_3) over fertigation at 1.0 Epan with 100 per cent recommended dose of fertilizers through conventional fertilizers (N, K through fertigation and P as basal soil application) in *rabi* maize. By adopting drip irrigation in pigeonpea at farmer's field, the highest seed yield of 33 q ha^{-1} was recorded in Hingne village of Jalgaon district in Maharashtra (Anil Jain, 2010). Muthukrishnan and Anitta Fanish (2011) recorded higher maize grain yield (7300 kg ha^{-1}) under drip fertigation of 100 per cent RDF with 50 per cent P and K through water soluble fertilizer (WSF) followed by application of 150 per cent RDF through drip (7050 kg ha^{-1}). The yield increase over drip irrigation with soil application of fertilizer was 39 per cent. Mahalakshmi *et al.* (2011) reported that drip irrigation with 0.8 Epan throughout the crop period of pigeonpea recorded the higher grain yield of 3731 kg ha^{-1}. Latha *et al*. (2012) reported that direct sown pigeonpea (CO 6) at single row per lateral with 10 split application of N and K through drip fertigation + 100 per cent WRc recorded the highest grain yield (1486 kg ha^{-1}), net income and B:C ratio over different spacing in transplanted pigeonpea in the Western Zone of Tamil Nadu. Vimalendran and Latha (2014) revealed that drip irrigation at 100 % WRc with fertigation at 125 % RDF through WSF registered significantly highest grain yield of 2812 and 2586 kg ha^{-1}during 2011-12 and 2012-13, respectively.

Effect of drip fertigation on water saving and water use efficiency: Water use efficiency is the yield of marketable crop produced per unit of water used in evapotranspiration. In the absence of new irrigation projects, bringing more area under irrigation would mostly rely on the efficient use of water. In this context, micro irrigation could play a key role in higher productivity and increased water use efficiency besides fulfilling sustainability mandates with economy in use. Adoption of micro irrigation helps in raising the irrigated area, crop productivity and WUE . Drip irrigation in tomato at 75 per cent of CPE recorded the highest WUE (53.7 kg ha^{-1} cm^{-1}) as compared to furrow irrigation. Prabhakar (1999) reported that irrigation at 0.5 evaporation loss replenishment level resulted in higher water use efficiency of 42.7 kg ha^{-1} mm^{-1} when compared with furrow irrigation (24.7 kg ha^{-1} mm^{-1}). Drip fertigation at 180 kg N ha^{-1} provided 40 per cent saving in water and 52 per cent higher yield over check basin method of irrigation and the WUE was also higher in drip fertigation at 180 kg N ha^{-1} followed by drip fertigation at 135 kg N ha^{-1} (Singh *et al*., 1999). Veeranna *et al*. (2000) reported that drip irrigation method produced significantly higher dry chilli yield with 42 per cent higher water use efficiency over furrow method of irrigation even with the same level and method of normal fertilizer application. Vishwanatha *et al*. (2000)

reported that water use efficiency was significantly higher in drip irrigation at 0.4 Epan (40.04 kg ha^{-1} mm^{-1}) over 0.6 and 0.8 Epan (33.27 and 32.69 kg ha^{-1} mm^{-1}), which were significantly better than weekly surface irrigation at 0.8 Epan (27.19 kg ha^{-1} mm^{-1}) during summer 1998 in red sandy loam soil of Bangalore.

Raskar and Bhoi (2001) found 20 to 30 per cent increase in cane yield and 42 to 52 per cent total water savings with drip irrigation. The water use efficiency ranged from 1.017 to 1.403 t ha cm^{-1} in drip irrigation compared to 0.48 to 0.60 t ha cm^{-1} in surface method. Ertek and Kanber (2001) reported that the WUE and irrigation water use efficiency (IWUE) varied from 0.58 to 0.62 kg m^{-3} and 0.75 to 0.94 kg m^{-3}, respectively in cotton irrigated by a drip system. Patil *et al*. (2008) stated that scheduling of drip irrigation in hybrid cotton at 50 per cent potential evapotranspiration throughout the crop growth period would save 50 per cent irrigation water and enhanced WUE (53.2 g $ha^{-1}cm^{-1}$) and cotton productivity without affecting quality on a medium black soil and pointed out that under water scarcity area or low rainfall years, drip irrigation is better than alternate furrow irrigation method for obtaining higher water use efficiency and yield.

Drip irrigation produced significantly higher dry chilli yield with 42 per cent higher water use efficiency over furrow method (Veeranna *et al*., 2000). Drip fertigation experiments carried out at Syria to study the effect of drip fertigation in cotton indicated saving of 35 per cent of irrigation water under drip fertigation system compared to surface method of irrigation (Janat and Somi, 2001). Drip irrigation at 0.8 Epan with normal planting recorded higher water use efficiency (WUE) of green cob and fodder with total water requirement of 330.5 mm for sweet corn (Viswanathan *et al.,* 2002).

The results of drip irrigation experiment conducted at Mahatma Phule Agricultural University, Rahuri, India indicated that water use efficiency in drip irrigated tomato, on an average was 68 and 77 per cent higher over surface irrigation during 1995 and 1996, respectively (Singandhupe *et al*., 2003). Irrigation water use efficiency was increased by 89 per cent over surface irrigation when scheduling was done following the 70-70-60 per cent of field capacity during each of the three major growth stages, respectively in cotton (Nazirbay *et al*., 2003).

The results obtained from the experiment with four different IW/CPE ratios of 125, 100, 75 and 50 per cent in watermelon indicated that under conditions of unlimited water, 125 per cent treatment seemed to be the best. However, 75 per cent treatment might be a better choice under limited water, because with this treatment, 32.6 per cent water saving was possible even though this application resulted in 26.2 per cent reduction in the crop yield (Simsek *et al.,* 2005). Corn and peanut were irrigated daily at 100, 75 and 50 per cent of estimated crop water use for each crop. There was no yield reduction in these crops when irrigating at 75 per cent of the estimated water use compared with the 100 per cent irrigation level (Sorensen and Butts, 2005). Muthukrishnan and Anitta Fanish (2011) noticed that drip irrigation helped to save water upto 43.65 per cent compared to surface irrigation method. Among the irrigation levels, drip irrigation scheduled at 0.6 Epan resulted in higher WUE (122 kg ha^{-1} mm^{-1}) and the least WUE (95 kg ha^{-1} mm^{-1}) was recorded at 1.0 Epan in tomato under sandy clay loam soil (Vijay Kumar *et al*., 2012).

Economics: One of the main objectives of fertigation is to reduce the cost of cultivation and to increase the economic product as high as possible. Therefore getting maximum benefits from each unit of water and nutrient applied to crop are important. A technically feasible level of fertigation with straight and water soluble fertilizer through drip would be economically viable for its successful adoption. Drip irrigation at 100 per cent WRc with 100 per cent recommended dose of fertilizers registered the highest additional net income of Rs 1,23,679 ha^{-1} and B:C ratio of 3.30 which was closely followed by drip irrigation at 80 per cent WRc with 100 per cent RDF registering an additional net income of Rs 1,19,488 and BCR of 3.23 over surface irrigation (Selvakumar, 2006). Praharaj and Narendra Kumar (2011) reported that an additional net monitory return of Rs. 9000 ha^{-1} $annum^{-1}$ by drip fertigation of pigeonpea at branching and pod development stage with NK @ 10:10 kg ha^{-1} in 5-10 split doses. From the foregoing review, it could be clearly seen that pigeonpea also well respond to the split application of nutrients and irrigation and this methods requires less irrigation water with increased irrigation efficiency and ensure uniform distribution of water and nutrients as compared to surface methods. Fertigation in pigeonpea also increases the nutrient use efficiency, which leads to increase in yield and economic returns. This methods also ensures the doubling the yield with optimum levels of irrigation and fertilizers usage.

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