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Effect of Drip Fertigation and Mulching on Pulses Cultivation: A Review

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ABSTRACT

The present paper discusses the efficacy of drip fertigation and mulching in production of pulse crops viz. Pigeon pea, Chick pea and field Pea cultivated in Indian sub-continent. The paper presents a comprehensive account of the effect of drip irrigation, fertigation and mulching on growth, yield, water use efficiency and economics of pulse crop cultivation and identifies the research and developmental gaps that need immediate attention of the researchers. The review indicated that drip irrigation saved 20–48% of irrigation water over surface irrigation methods and improved the crop yield by 10–20%. Adoption of fertigation in pulse crops also resulted in better plant growth and yield of pulse crops and was effective in reducing the losses of nutrients by leaching. It was observed that drip irrigation and mulching had a synergic effect on major yield attributes which ultimately manifested in improved yield of pulse crops.

Keywords Chick pea, Pigeon pea, Pea, Drip irrigation, Plastic mulching.

INTRODUCTION

Pulses are an important source of protein in the diet of Indian population. Although, about 16% of total cultivable land is used for cultivation of pulse crops, the production is not enough to fulfill the recommended demand of per capita pulse intake for human consumption. The average consumption of pulses is about 31 g per consumption unit per day (g/CU/day), which is lower than the recommended level of 40 g/CU/day (NNMB 2012). The major pulse crops in India are red gram or pigeon pea (arhar), chick pea or bengal gram (chana), green gram (moong), black gram (urad) and lentils (masoor). The total pulses production is 23.15 million ton from cultivated area of 28.34 million ha during 2019-2020 (Agricultural Statistics at a Glance 2020).

India is the world's largest producer and consumer of pulses accounting about 27% of the total production and about 30% of the total consumption in the world. India has an average productivity of pulse crops is about 739 kg/ha which is significantly lower as compared to the world average (910 kg/ha) (Agricultural Statistics at a Glance 2020).

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Water and nutrients are the two most critical inputs in crop production and their efficient management is important not only for higher productivity & quality but also to maintain the environmental sustainability. The micro irrigation systems particularly, drip and sprinkler methods are most efficient and increasingly adopted worldwide for crop cultivation. Fertigation allows nutrient placement directly into root zone of crop during critical periods of nutrient demand (Mali *et al.* 2017). Mulching is the practice of covering the soil or growing media for creating more favorable conditions of root zone for better plant growth, development and crop production.

Over the last two decades, adoption of drip fertigation with mulching has been used extensively for crop cultivation (Biswas *et al.* 2015). Researchers have evaluated the impacts of these two basic management practices on range of pulse crops cultivation. Most of these studies are crop specific and are scattered over many agroclimatic regions. The paper aims at presenting a critical review on drip irrigation and mulching practices in pulse crops with a focus to highlight recent trends in water management of pulse crops and present the thrust areas for future research. The aspects like constraints in pulse production and effect of drip fertigation and mulching on pigeon pea, chick pea and pea cultivation are also discussed.

Pulse production in India

There was 28.34 million ha area under pulses production during 2019-20 in India, which was mainly contributed by Rajasthan, Maharashtra, Madhya Pradesh, Uttar Pradesh and Karnataka. The production of peas, chick peas and pigeon pea during 2013-14 to 2019-20 is given in Table 1.

Maharashtra has the largest production of pulses in *kharif* season followed by Rajasthan & Uttar Pradesh and Madhya Pradesh has the largest production of pulses during *rabi* season followed by Uttar Pradesh & Andhra Pradesh as shown in Fig. 1.

Constraints and drivers of pulse production in India

The non-availability of seeds of high yielding varieties in the desired quantities, number of diseases & insect pests, costlier phosphatic & potassic fertilizers compared to the nitrogenous fertilizers had adverse impact on the production of pulse crops in India.

Table 1. Domestic production of pigeon pea, chick pea and peas. Source: Agricultural Statistics at a Glance 2020.

Pulses	Production (million tones)						
	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Pigeon pea	3.17	2.71	2.56	4.87	4.29	3.32	3.83
Chick pea	9.53	7.59	7.06	9.38	11.23	9.94	11.35
Peas	3.87	4.65	4.81	5.35	5.44	5.56	5.79

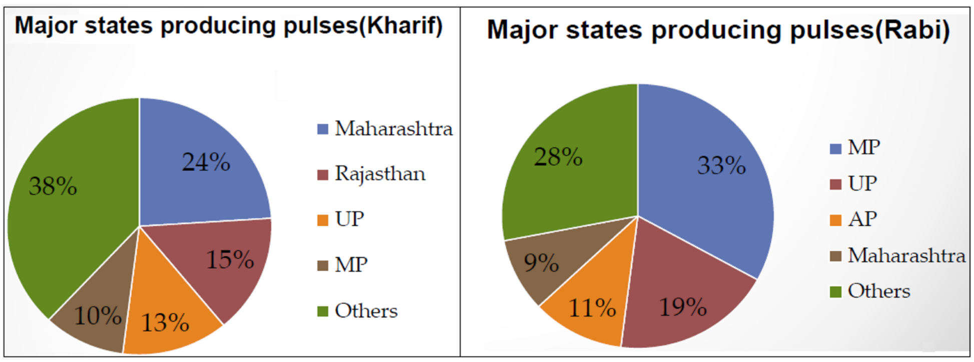

Fig. 1. State wise statistics of pulses in India. Source: Directorate of economics & statistics, DAC & FW, GOI.

Table 2. Effect of drip fertigation condition on crop growth.

Sl. No.	Crop	Drip irrigation condition	Fertigation condition	Crop growth parameters	Reference
1	Pigeon pea	Drip irrigation at 100% ET	Fertigation, 125:100: 100% RDF	Plant height (241 cm), number of branches per plant (48.32)	Kakade *et al.* (2017)
2	Chick pea	Drip irrigation at 100% soil water deficit	Conventional	Plant height (37.5 cm), biomass (6.083 kg/ha)	Dogan *et al*. (2013)
3	Chick pea	Drip irrigation at 0.8 PEF	Conventional	Plant height (39.2 cm), plant spread (31.8 cm), number of branches per plant (5.9), number of pods per plant (37.2)	Solanki *et al.* (2013)
4	Chick pea	Drip irrigation	Conventional	Plant population in m^{-2} (28), plant height (40.5 cm), number of branches plant^{-1} (25.3), dry matter production (34.67 g plant^{-1})	Kumar *et al*. (2017)
5	Chick pea	Drip irrigation at 100% E_{pan}	Conventional	Plant height (43.7 cm), number of branches (3.5), total dry matter production plant (9.53 g/ plant)	Muniyappa *et al.* (2017)
6	Chick pea	Drip irrigation at 100% ET	Conventional	Plant height (50.49 cm), leaf area index (2.54)	Singhal *et al*. (2018)
7	Chick pea	Drip irrigation	Fertigation	Plant height (40.1 cm), number of branches per plant (8) number of pods per plant (105), number of seeds per pod (2)	Rai and Singh (2019)
8	Pea	Drip irrigation at 100% soil water deficit	Conventional	Plant height (59 cm), biomass (11,697 kg/ha)	Dogan *et al.* (2013)
9	Pea	Micro-sprinkler pan evaporation	Fertigation, 50% NPK	Plant height (59.7 cm), number of branch per plant (3.4), number of pods per plant (18.7)	Rao *et al*. (2017)
10	Pea	Drip irrigation	Fertigation	Plant height (59.8 cm), number of branches per plant (4), number of pods per plant (33), number of seeds per pod (5)	Rai and Singh (2019)

Accelerated pulses production program (A3P) has been launched as part of National Food Security Mission (NFSM) since 2010-11 where under one million hectare of potential pulses areas for the major pulses crops have been taken up for large scale demonstration of technology. Moreover, with a view to incentivize the farmers to increase the production and productivity of pulses, the government of India has substantially raised the Minimum Support Price (MSP) of pulses (www. desagri.gov.in).

Drip fertigation in pulse crops

Water is the very important for plants to accomplish their metabolic, photosynthesis and evapotranspiration activities. The assured irrigation facility has a high priority where production of food has to keep pace with a rapidly increasing population. The availability of irrigation water is major challenge currently our crop cultivation is facing. Though India has the largest irrigation network but the irrigation efficiency seldom exceed 40%. To further expand the cultivation area depends upon efficient irrigation system such as micro-irrigation system (Kumar *et al.* 2016). In India, due to special emphasis on micro-irrigation under PMKSY (Pradhan Mantri Krishi Sichai Yojna) scheme with higher levels of subsidies provided by the government to the farmers that total irrigated area

Table 3. Effect of drip fertigation condition on yield.

Sl. No.	Crop	Irrigation condition	Fertilization	Yield (t/ha)	Reference
1	Pigeon pea	Drip irrigation at 100% WRc	Fertigation, 125% RDF	2.69	Vimalendran and Latha (2014)
2	Pigeon pea	Drip irrigation	Fertigation	1.42	Manikandan and Sivasubramaniam (2015)
3	Pigeon pea	Drip irrigation at 100% WRc	Fertigation, 125% RDF	2.70	Loganathan and Latha (2016)
4	Pigeon pea	Drip irrigation	Fertigation, 125% RDF	1.99	Jeyajothi and Pazhanivelan (2017)
5	Pigeon pea	Drip irrigation at 100% ET	Fertigation, 125:100: 100% RDF	3.87	Kakade *et al.* (2017)
6	Pigeon pea	Drip irrigation	Conventional	3.47	Praharaj *et al.* (2017)
7	Chick pea	Drip irrigation	Conventional	2.24	Sawargaonkar *et al.* (2012)
8	Chick pea	Drip irrigation at 100% soil water deficit	Conventional	1.96	Dogan *et al.* (2013)
9	Chick pea	Drip irrigation at 0.8 PEF	Conventional	1.69	Solanki *et al.* (2013)
10	Chick pea	Drip irrigation	Conventional	1.18	Kumar *et al.* (2017)
11	Chick pea	Drip irrigation at 100% t E_{pan}	Conventional	1.78	Muniyappa *et al.* (2017)
12	Chick pea	Drip irrigation at 100% ET	Conventional	2.05	Singhal *et al.* (2018)
13	Chick pea	Drip irrigation	Fertigation	1.33	Rai and Singh (2019)
14	Pea	Drip irrigation	Fertigation	6.15	Aziz *et al.* (2008)
15	Pea	Drip irrigation	Fertigation	11.2	Khanday *et al.* (2012)
16	Pea	Drip irrigation at 100% soil water deficit	Conventional	3.48	Dogan *et al.* (2013)
17	Pea	Micro-sprinkler at 0.8 CPE	Fertigation, NK only	10.76	Saroch *et al.* (2015)
18	Pea	Micro-sprinkler at pan evaporation	Fertigation, 50% NPK	9.81	Rao *et al.* (2017)
19	Pea	Drip irrigation	Fertigation	2.5	Rai and Singh (2019)

under the micro irrigation has increased. In India, traditional pulse cultivators are not using drip irrigation system. Adopting drip irrigation with proper fertigation can reduce the negative impacts of surface irrigation & fertilization and provides better water use & fertilizer efficiency.

Table 2 shows that the effect of drip fertigation

Table 4. Effect of drip fertigation condition on water use efficiency.

Sl. No.	Crop	Irrigation condition	Fertilization	Water use efficiency	Reference
1	Pigeon pea	Drip irrigation at 100% WRc	Fertigation at 125% RDF	6.97 kg/ha-mm	Vimalendran and Latha (2014)
2	Pigeon pea	Drip irrigation	Conventional	6.51 kg/ha-mm	Praharaj *et al.* (2017)
3	Chick pea	Drip irrigation	Conventional	1.11 kg/m^3	Sawargaonkar *et al.* (2012)
4	Chick pea	Drip irrigation at 100% soil water deficit	Conventional	4.55 kg/ha-mm	Dogan *et al.* (2013)
5	Chick pea	Drip irrigation at 0.8 PEF	Conventional	4.88 kg/ha-mm	Solanki *et al.* (2013)
6	Chick pea	Drip irrigation	Conventional	4.71 kg/ha-mm	Kumar *et al.* (2017)
7	Chick pea	Drip irrigation at 100% E_{pan}	Conventional	6.35 kg/ha-mm	Muniyappa *et al.* (2017)
8	Pea	Drip irrigation	Fertigation	2.69 kg/m^3	Aziz *et al.* (2008)
9	Pea	Micro-sprinkler at 0.8 CPE	Fertigation, NK only	6.51 kg/m^3	Saroch *et al.* (2015)
10	Pea	Micro-sprinkler at pan evaporation	Fertigation, 50% NPK	2.65 kg/m^3	Rao *et al.* (2017)

Table 5. Cost economics for pulses cultivation.

Sl. No.	Crop	Irrigation condition	Fertilization	Net income (Rs/ha)	B:C ratio	Reference
1	Pigeon pea	Drip irrigation at 100% ET	Fertigation, 125:100: 100% RDF	1,55,938	4.10	Kakade *et al*. (2017)
2	Pigeon pea	Drip irrigation	Conventional	76,050	–	Praharaj *et al.* (2017)
3	Chick pea	Drip irrigation	Conventional	88,992	3.26	Sawargaonkar *et al.* (2012)
4	Chick pea	Drip irrigation at 0.8 PEF	Conventional	23,066	1.84	Solanki *et al*. (2013)
5	Chick pea	Drip irrigation	Conventional	47,120	2.03	Kumar *et al*. (2017)
6	Chick pea	Drip irrigation at 100% E_{pan}	Conventional	31,793	1.86	Muniyappa *et al.* (2017)
7	Pea	Micro-sprinkler at 0.8 CPE	Fertigation, NK only	1,34,508	2.20	Saroch *et al*. (2015)

under optimum condition on crop growth parameters for pigeon pea, chick pea and pea. The authors have compared drip irrigation with surface irrigation with irrigation at various levels. In majority of experiments fertilizer was applied as basal dose but in some experiments, fertigation has been done. The plant growth parameters were better under drip fertilization in comparison to surface irrigation with basal dose of fertilizer. The better crop growth under drip fertigation is due to optimum soil moisture and application of the water-soluble fertilizer at the site of high concentration of active roots with a greater number of splits which might have resulted in higher availability & higher uptake by the roots and ultimately resulted in better crop growth.

The Table 3 shows that the effect of drip fertigation under optimum condition on yield of pigeon pea, chick pea and pea. The increased yield under drip fertigation might be due to enhanced the assimilation efficiency resulting in increased number of leaves per plant, better branching and LAI, which contributed for higher dry matter production. Whereas in the basal dose of fertilizers, the fertilizers were applied in excess on the soil with minimum number of splits. So, the availability of nutrients would be very high during initial days, but at reproductive stage the applied nutrients would have been depleted or leached off and not available to the crops which might have resulted in lower yield of the crops.

The Table 4 shows that the effect of drip fertigation under optimum condition on water use efficiency for pigeon pea, chick pea and pea. The water use efficiency was best under drip fertigation in comparison to other treatments due to better management of irrigation water.

The Table 5 shows that the effect of drip fertigation under optimum condition on economics of cultivation for pigeon pea, chick pea and pea by net income and B : C ratio. One of the main objectives of drip fertigation is to reduce the cost of cultivation and increase the economics of cultivation as high as possible.

The scientists around the world are working to make farming profitable and sustainable. The proper input management plays a very vital role in making farming activities sustainable while keeping environment impact into consideration. The proper nutrient management as per plant uptake for N (Greenwood *et al.* 1990), which is the plant nutrient of greatest concern because of the negative impacts of N losses on water quality and greenhouse gas emissions (Galloway and Cowling 2002) and the fertigation avoids excessive leaching of nutrients (Hagin and Lowengart 1996). Fertigation enables the application of N and other nutrients in multiple small doses that can be timed to according to crop demand.

Mulching in pulse crops

Mulching is an agricultural technique by placing or-

Table 6. Effect of drip fertigation and mulching yield, economics and water use efficiency for pulses cultivation.

Sl. No.	Crop	Irrigation & fertilization	Mulching	Yield (kg/ha)	Net income (Rs/ha)/ B:C ratio	Water use efficiency	Reference
1	Pigeon pea	Surface	Soil, sugarcane trash, black polyethylene mulch	51.56% increase in yield under black plastic mulch over no mulch	-	-	Gajera (1994)
2	Pigeon pea	Surface	Sugarcane trash (8t/ha), black polyethene mulch	-	-	-	Gajera *et al.* (1998)
3	Pigeon pea	-	Soil, wheat straw (5 t/ha), groundnut shell (10 t/ha), castor shell mulch	-	-	-	Vadi *et al.* (2006)
4	Pigeon pea	Drip irrigation	Sugarcane trash mulch (5 t/ha), black plastic mulch (25 micron)	1732	45789	3.4 kg/ha-mm	Patel *et al.* (2015)
5	Pigeon pea	Drip irrigation & fertilization	Sugarcane trash mulch (5 t/ha), black plastic mulch (50 micron)	1774	-	49% water saving compared to surface irrigation	Savani *et al.* (2017)
6	Pigeon pea	Drip irrigation & fertilization	Silver-black mulch (25 micron)	2302	-	-	Swathi *et al.* (2017)
7	Chick pea	Conventional	Polypropylene woven mulch, black plastic mulch	2029	-	-	Komal *et al.* (2018)
8	Pigeon pea	Drip irrigation	Silver-black (25 micron)	3800	-	-	Rai *et al.* (2019)
9	Pigeon pea	Drip irrigation & fertilization	Sugarcane trash mulch (5 t/ha), black plastic mulch (50 micron)	3319	136476/ 3.66	6.84 kg/ha-mm	Solanki *et al.* (2019)
10	Pigeon pea	Drip irrigation	Black plastic sheet (25 micron), wheat straw (5 t/ha)	1751	59392/ 1.64	13.7 kg/ha-mm	Jadav *et al.* (2020)
11	Pigeon pea	Surface irrigation	Straw mulching (5 t/ha, 10 t/ha)	3240	-	-	Nisha and Dhillon B.S. (2020)
12	Pigeon pea	Drip irrigation	Black plastic sheet (25 micron), wheat straw (5 t/ha)	2091	59392/ 1.64	-	Jadav *et al.* (2022)
13	Pigeon pea	Drip irrigation & fertilization	Plastic mulching (25 micron)	3923	63488/ 2.49	9.12 kg/ha-mm	Kumar *et al.* (2022)
14	Red gram	Surface fertilization	Raw coconut coir pith (12.5 t/ ha), sugarcane trash (5 t/ha), black plastic mulch (7.5 micron)	1738	1.49	1.50 kg/ha-mm	Duraisamy and Man-ickasunda-ram (2008)
15	Pea	Drip and surface	Black plastic mulch (25 micron), hessian cloth mulch (50% shade jute cloth), indigenous plant material (laptodoniaspps @ 10 t/ ha) mulch	7651	-	-	Birbal *et al.* (2013)

ganic or inorganic materials on the soil around plants to provide a more favorable environment for plant growth and production. Depending upon material, it affects loss of water by evaporation, suppress weeds growth, modifying soil temperature, insect repelling, reflection of light for enhancing photosynthesis, enhancing the fruit quality, changing the micro climate around the plant (Rai *et al*. 2017).

Organic mulches are those derived from plant and animal materials. Due to its biodegradable nature, it helps in maintaining soil organic matter, tilth, food for earthworms and other desirable soil biota (Tindall *et al.* 1991). But the challenges are temporary reduction in soil mineral nitrogen, release of the natural phytotoxins, availability in sufficient & consistent quality, higher labor for spreading, not proper weed control, adequate soil warming, harbor pests, do not cause higher yields (Subrahmaniyan and Zhou 2008).

To overcome some of the problems outlined above, plastic mulches have been developed for use in agriculture. The plastic mulches i.e. clear, black, reflective mulch, wavelength-selective mulches, colored mulches and degradable mulches have been extensively studied on vegetables cultivation (Rai *et al.* 2017). The primary function of plastic mulching is soil heating & cooling and air warming apart from other secondary benefits (Lamont Jr 1993) and major disadvantages are cost of mulching material, removal & disposal of mulching materials (Kyrikou and Briassoulis 2007).

The best utilization of mulch can be done with drip irrigation or drip irrigation with fertigation facility. The limited number of organic and plastic mulches has been tested for pulses cultivation and its effect on plant growth.

The Table 6 shows that the effect of drip fertigation with mulching under optimum condition on yield, economics of cultivation (net income and B : C ratio) and water use efficiency for pigeon pea, chick pea and pea. The growth, yield, economics of cultivation and water use efficiency of pulses crop are better under drip fertigation with mulch due to favorable root zone condition in comparison to surface irrigation with fertilization (basal dose & broadcasting) under without mulch condition.

Focus of future research

Though benefits of water & nutrient saving and cost economics for vegetables cultivation is well established and extensively used by farming communities but for pulses production limited number of studies has been conducted by research scientists and more studies need to be conducted. The water and fertigation scheduling under different cultivation practices (surface irrigation, drip system, drip fertigation & drip fertigation with mulch) for pulses crop at same site under same agro climatic condition will be different and detail studies in these areas need to be conducted. A lot of work has been reported on automation of drip irrigation system based on tensiometer, soil moisture sensor but its affordability and application at farmer's field is rarely visible.

The fertigation scheduling mainly depends on crop & site specific nutrient requirements and timely nutrient delivery to meet crop needs. The recommended dose of fertilizer available for any crop at research institute & Agricultural University is normally given for surface irrigation not for cultivation under drip system, drip fertigation & drip fertigation with mulch. The EC & pH of water, EC & pH of fertilizer source, EC & pH of soil, EC & pH of fertigation solution and behavior of EC & pH under fertigation condition under soil plays very vital role in fertigation of any crop.

The impact of mulching on yield of pulses is well documented but the effect of mulching materials on quality of pulse production is not reported though it well researched on vegetables production (Kim *et al.* 2006). The new generation photo selective and colored mulch are available in market but some more studies are required in this area to take best advantage of its property in pulses cultivation (Dinmani *et al.* 2018). The studies on photo degradable/bio-degradable mulch are also reported in literature but apart from its better understanding its cost is major hindrance in its wider applicability. The removal and recycle of plastic mulches is big challenge and it needs to be tackled.

CONCLUSION

The results obtained for drip system, drip fertigation & drip fertigation with mulch for pigeon pea, chick pea & pea cultivation have been very encouraging but there are many issues which need to be resolved by continuous and focused research. Hence, the research workers/scientist need to validate drip system, drip fertigation & drip fertigation with mulch for growing pulses in their local regions, so that the locally obtained results of research work may be passed as recommendation/farming practices to farmers. It is well known that fertilizer use efficiency of NPK is very low under conventional application in comparison to fertigation. The wider application of micro irrigation with fertigation will not only reduce the burden of subsidies but it will also address the environmental concerns.

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