Optimizing water utilization to enhance pulse production : A review

❖ Abstract

Pulses are a crucial group of crops that supply high-quality protein to complement the protein found in cereal crops for the large vegetarian population. Water scarcity and inefficient water management pose significant challenges to pulse production, which is crucial for food security and sustainable agriculture. This paper focuses on optimizing water utilization in pulse production to enhance crop yields and mitigate the impact on water resources. We explore various strategies and technologies that can improve water-use efficiency, including precision irrigation techniques, soil moisture monitoring, water-saving practices, and genetic improvement programs for drought-tolerant varieties. Additionally, we discuss the benefits of agroforestry systems and crop rotation in enhancing water infiltration and soil health. By implementing these measures, farmers can optimize water utilization, increase pulse yields, and contribute to sustainable agricultural practices. This research highlights the importance of addressing water scarcity in pulse production to ensure food security in the face of changing climatic conditions and growing population demands.

Key word: climatic conditions, soil health, water utilization , pulse production

❖ Introduction

Water scarcity is a pressing global challenge that poses significant threats to agriculture and food security. As the world population continues to grow, the demand for nutritious and sustainable food sources escalates, necessitating a more efficient use of water resources in agricultural practices. Pulses, including beans, lentils, chickpeas, and peas, are vital crops that contribute to a balanced diet, soil fertility, and climate resilience (Praharaj *et. al.,* 2015). However, their production is highly dependent on adequate water availability and efficient water management strategies. In many regions, the cultivation of pulses faces formidable obstacles due to limited water supplies, erratic rainfall patterns, and inefficient irrigation practices (Patra *et. al.,* 2021). Addressing these challenges requires a comprehensive approach that combines scientific knowledge, technological advancements, and sustainable agricultural practices. By optimizing water utilization in pulse production, farmers can not only increase their crop yields but also reduce the overall water footprint and mitigate the impact on water resources.

This paper explores the importance of water management in pulse production and highlights various strategies and technologies that can enhance water utilization efficiency. We examine the potential benefits of precision irrigation techniques, such as drip irrigation and controlled deficit irrigation, in maximizing water productivity (Singh *et. al.,* 2010). Additionally, we discuss the importance of soil moisture monitoring and the implementation of water-saving practices, such as mulching and conservation tillage, to reduce evaporation and enhance water retention in the root zone. Furthermore, we delve into the role of crop breeding and genetic improvement programs in developing drought-tolerant pulse varieties that require less water without compromising yield and quality (Rao *et al.*, 2018). We also explore the significance of agroforestry systems and crop rotation in pulse production, as they contribute to better water infiltration, nutrient cycling, and overall soil health. By adopting these strategies and technologies, farmers can optimize water utilization in pulse production, resulting in increased yields, improved water-use efficiency, and enhanced resilience to water scarcity. Furthermore, such measures can contribute to sustainable agricultural practices, minimize environmental degradation, and ensure food security in the face of changing climatic conditions (Rani and Sudhakar, 2018).

❖ Kharif and Rabi pulses

Kharif is a term used in South Asia to describe the monsoon or summer season, typically occurring between June and October and typically Rabi pulses falls between October and April, and is characterized by cool and dry weather conditions

Kharif pulses	**Rabi pulses**
Black gram (Urad)	Lentil
Green gram (Moong)	Chickpeas (Chana)
Red gram (Tur)	Field pea
Field beans (Lobia)	Peas
Cowpeas (Chawli)	
Pigeon peas (Arhar)	

❖ Agronomic strategies to enhance water use efficiency

Means are improved agronomic managements practices which help in increasing pulse prodction. Following means are listed below

1. Cropping systems and crop rotation
2. Selection of varieties
3. Method of sowing and spacing
4. Irrigation
    A. Methods of irrigation
    B. Scheduling of irrigation
    C. Stage of irrigation
5. Fertilization
6. Moisture conservation and reducing water loss
7. Weed management
8. Pest management

2.1 Cropping systems and crop rotation

- A cropping system refers to the type and sequence of crops grown and practices used for growing them. Selecting best cropping system play a very important role in increasing the yield of crop and reducing the evaptranspirarion.
- Incorporating pulse crops into a crop rotation system can help to improve soil health, reduce pest and disease pressure, and increase yield.
- Intercropping – growing two or more crop on same piece of land with a definite row arrangement complementary sharing of plant resources, such as Nitrogen from N fixing plants and additional weed suppression, and a reduction in susceptibility to insects and disease.

  Additive series intercropping is prevalent in India, Where one crop is main crop and other is intercrop. Growing of base crop with best intercrop particularly legumes (green gram, cowpea) at definite row proportion will help to get higher yield and ultimately increasing WUE in pigeonpea (Mathukia *et al.*2015).

Table 1: Pigeonpea equivalent yield, stalk yield and water use efficiency (WUE), of pigeonpea as influenced by cropping system

Treatments	**Pigeonpea equivalent yield(q ha^{-1})**	**Stalk yield (q ha^{-1})**	**WUE (kg ha-mm^{-1})**
Cropping system			
Sole pigeonpea	16.14	75.6	6.69
Pigeonpea+ urdbean (1:1)	17.4	79.0	6.94
C.D. at 5%	NS	NS	-

Krishnaprabhu, 2019 studied the pigeonpea equivalent yield, stalk yield and water use efficiency (WUE), of pigeonpea as influenced by cropping system among the treatment pigeonpea+ urdbean (1:1) intercropping system has recorded higher water use efficiency (6.94 kg ha-mm^{-1}) and pigeonpea equivalent yield (17.4 kg ha^{-1}) compared to other treatment because intercropping urbean which act as mulch crop which reduce evaporation and Intercropping allows for the more efficient utilization of resources such as light, water, and nutrients. The different crops can use these resources in complementary ways, leading to higher overall yields

Table 2: Effect of pigeonpea (PP) + greengram (GG) intercropping system on water use efficiency (WUE), pigeonpea equivalent yield (PEY) and yield of pigeonpea

Tr. No.	Treatments	WUE (kg ha-mm^{-1})	PEY (q ha^{-1})	Seed yield (q ha^{-1})	Stalk yield (q ha^{-1})
T_1	Sole Pigeonpea	2.56	14.46	14.46	31.90
T_2	Sole Greengram	1.83	13.34	-	-
T_3	PP + GG (1:1) - Flat bed	2.30	18.94	12.98	28.91
T_4	PP + GG (1:2) - Flat bed	2.41	20.01	13.58	29.60
T_5	PP + GG (2:4) - Flat bed (paired row)	2.07	17.55	11.69	25.46
T_6	PP + GG (1:1) - Set-furrow	2.76	22.64	15.56	33.36
T_7	PP + GG (1:2) - Set-furrow	2.92	24.10	16.45	35.73
T_8	PP + GG (2:4) - Set-furrow	2.32	19.95	13.10	28.36
T_9	PP + GG (1:2) - Set-furrow + Vermicompost @ 2.5 t ha^{-1}	2.99	24.60	16.85	36.57
	Mean	2.46	19.51	14.34	31.24
	S.Em ±	0.10	0.72	0.69	1.17
	C.D. at 5%	0.31	2.17	2.11	3.56

Sharma and Guled, 2012 studied on the effect of pigeonpea (PP) + greengram (GG) intercropping system on water use efficiency (WUE), pigeonpea equivalent yield (PEY) and yield of pigeonpea among the treatments pigeonpea + greengram (1:2) - Set-furrow + Vermicompost @ 2.5 t ha^{-1} has recorded higher water use efficiency (2.99 kg ha-mm^{-1}) and pigeonpea equivalent yield (24.64 kg ha^{-1}) compared to other treatment because intercropping greengram which act as mulch crop which reduce evaporation, act as green manure crops and even as a legume it fix atmospheric nitrogen and addition of 2.5 t ha^{-1} of vermicompost improves soil physical properties and set furrow cultivation reduces runoff and increase water availability and result are in accordance with work done by (Praharaj *et. al.,* 2015).

2.2 Selection of varieties

The selection of crop varieties is an important factor in increasing pulse production. Here are some key considerations when selecting varieties:

1. Adaptation: Choose varieties that are well-adapted to the local growing conditions, such as soil type, climate, and water availability. This will increase the chances of successful crop establishment and high yields.

2. Yield potential: Look for varieties with a high yield potential and a history of good performance in similar growing conditions.

3. Disease and pest resistance: Consider varieties that are resistant to common diseases and pests in the area. This can help to reduce crop loss and increase yields.

4. Drought tolerance: For areas with limited water resources, select drought-tolerant varieties that can still produce high yields under water-stressed conditions.
5. Maturity: Choose varieties that mature at the appropriate time for the local growing conditions. This will help to ensure that the crops reach maturity before the onset of adverse weather conditions.

Table 3: Yield, harvest index and water use efficiency of pigeonpea as influenced by different varieties

Treatments	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	WUE (kg ha-mm^{-1})
Varieties					
BDN-711	1625	2797	4423	36.7	7.08
BSMR-736	1553	2644	4228	36.67	5.88
BDN-716	1691	2892	4589	36.79	8.28
S.Em ±	36.41	66.23	94.97	0.03	-
C.D. at 5%	106.78	194.22	278.49	0.088	-

Ganesh, 2017 reported yield, harvest index and water use efficiency of pigeonpea as influenced by different varieties, among the treatments pigeonpea variety (BDN-716) recorded higher WUE(8.28 kg ha-mm^{-1}) compared to BDN-711(7.08 kg ha-mm^{-1}) and BSMR-736(5.88 kg ha-mm^{-1}). The reason behind this is genetic character of variety BDN-716 - Spreading, deep root system, resistant to wilt and sterility mosaic, large seeded (12g/100 seeds) as a result of this which boosted the yield of crop and also increased the water use efficiency.

2.3. Method of sowing and spacing

Sowing method and spacing can greatly impact crop yield. Here are some ways to increase crop yield through these methods:

1. Proper sowing method: Sowing seeds at the correct depth and ensuring proper seed-to-soil contact can ensure better germination and establishment of plants.
2. Optimal spacing: Spacing plants properly can help increase yield by reducing competition for light, water, and nutrients. It also helps in better air circulation, reducing the incidence of diseases.
3. Row planting: Row planting allows for efficient use of space, ease of cultivation, and better exposure of the crop to sunlight.
4. Square foot gardening: In this method, crops are planted in small, closely spaced beds, and multiple crops are grown in a single bed. This maximizes the use of available space and increases yields.

5. Intercropping: Intercropping involves growing two or more crops in the same field at the same time. This helps to increase yields by making better use of the available resources, such as light, water, and nutrients.
6. Precision sowing: Precision sowing, using equipment such as seed drills, can help to ensure accurate planting and improve yields.

It's important to note that while these methods can help increase yields, the specific method used will depend on the type of crop, soil conditions, and local climate (Ram *et al.*, 2021).

Table 4: Water use efficiency (WUE), yield and harvest index (HI) of pigeonpea as influenced by of methods of planting

Treatment	WUE (kg ha-mm^{-1})	Seed yield (q ha^{-1})	Stalk yield (q ha^{-1})	HI (%)
M_1-Direct Sowing	3.36	2201	4415	29.7
M_2-Transplanting	4	2618	5040	31
S.Em ±	0.05	22.2	26.2	-
C.D. at (5%)	0.2	95.5	112.9	-

A study conducted at at ARS, Kalaburagi to evaluate water use efficiency (WUE), yield and harvest index (HI) of pigeonpea as influenced by of methods of planting, Among the treatments transplanted pigeonpea recorded higher WUE (4.0 kg ha-mm^{-1}) and higher significant yield (2618 qha^{-1}) compared to the direct sowing with yield (2201qha^{-1}) and WUE (3.36 kg ha-mm^{-1}). Because transplanting a healthy seed will grow luxuriously with proper root and shoot development which give room for proper uptake of nutrients and water results in higher yield and untimely higher water use efficiency (Rajesh**,** 2016)

Table 5: Yield, water use efficiency (WUE) and B:C ratio of pigeonpea as influenced by spacings

Treatments	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	WUE (kg ha-mm^{-1})	B:C ratio
Spacings				
120 cm x 30 cm	2199	3673	7.19	2.99
120 cm x 45 cm	2391	4077	7.82	3.41
120 cm x 60 cm	1998	3549	6.54	2.72

S.Em ±	66.06	138.53	-	0.100
C.D. at 5 %	193.77	406.33	-	0.295

Studies on the effect of spacing on yield, water use efficiency (WUE) and B:C ratio of pigeonpea among the treatments pigeonpea sowing at 120 cm x 45 cm recorded higher WUE (7.82 kg ha-mm^{-1}) and higher significant yield (2618 qha^{-1}) compared to sowing at spacing of 120 cm x 30 cm with yield (2199 kg ha^{-1}) and WUE (7.19 kg ha-mm^{-1}) and 120 cm x 60 cm with yield (1998 kg ha^{-1}) and WUE (6.54 kg ha-mm^{-1}) respectively .And this is because sowing at optimum geometry will give room for crop proper root and shoot development results in good uptake of water and nutrients will boost the crop yield and ultimetly increasing the productivity of crop. (Jadhav *et.al.,* 2018).

2.4 Irrigation

To increase pulse yield, the following irrigation requirements should be met:

1. Adequate watering: Pulses require consistent moisture to grow and produce high yields. Irrigate the field when the topsoil starts to dry out (Razzak *et al.*, 2022).
2. Proper timing: Timing of irrigation is critical in pulse production. Irrigate at flowering and pod-filling stages to ensure better yields.
3. Water management: Maintaining water at a consistent depth in the soil profile is crucial. Overwatering can lead to root rot and yield reduction (Rao *et al.,* 2016).
4. Quality of water: Using good quality water for irrigation is important as poor quality water can lead to disease and yield reduction (Ramesh and Rao, 2021).
5. Irrigation method: The choice of irrigation method depends on the soil type, water availability and crop requirements. Sprinkler and drip irrigation systems are popular for pulse crops (Payero *et. al.,* 2005) (Vimalendran and Latha, 2014).
6. Method of irrigation , Scheduling of irrigation and stage of irrigation plays a very important role in increasing the yield of crops(Pawar *et. al.,* 2013).

There are three main ways of applying irrigation water:

(1) Run the water over the soil surface and allow it to infiltrate, a method known as surface irrigation.

(2) Spray the water into the air and allow it to fall on to plants and soil as simulated rainfall. a method called sprinkler irrigation.

(3) Apply the water directly to the root zone, a method known as drip or sub-irrigation.

If one is successful in applying best method of irrigation will result in higher yield and water use efficiency, By meeting these irrigation requirements, you can improve the yield of pulse crops (Mishra *et al.* 2012) (Vishnu *et al.,* 2021).

Table 6: Yield, harvest index, consumptive use and water use efficiency of pigeonpea as influenced by different methods of irrigation

Treatments	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Harvest index (%)	Consumptive use (mm)	WUE (kg $ha\text{-}mm^{-1}$)
Methods of irrigation					
Check basin	902	1795	33.44	264.8	3.44
Drip irrigation	1347	2872	32.04	268.1	5.08
Border strip	1124	2109	34.73	266.3	4.46
S.Em ±	7.14	9.81	0.22	-	-
C.D.at 5%	22.02	30.23	0.76	-	-

Rawat, 2014 conducted a study and reported that yield, harvest index, consumptive use and water use efficiency of pigeonpea as influenced by different methods of irrigation, Among the treatments Drip irrigation has recorded higher WUE (5.08 kg $ha\text{-}mm^{-1}$) and higher significant yield (1347 kg ha^{-1}) compared to the border strip method of irrigation with yield (1124 kg ha^{-1}) and WUE (4.46 kg $ha\text{-}mm^{-1}$) and check basin method of irrigation with yield (902 kg ha^{-1}) and WUE (3.44 kg $ha\text{-}mm^{-1}$). Because of the advantages of drip method of irrigation, such as low evaporation, optimum moisture availability, uniform distribution of water and low water wastage as a result higher yield and water use efficiency is obtained under drip irrigation compared to other treatments where efficiency of these methods of irrigation was less and result are in accordance with work done by (Muniyappa *et. al.* 2017)

Table 7: Yield, water applied, harvest index and water use efficiency studies as influenced by irrigation stages of pigeonpea

Treatments	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Water applied (mm)	Harvest index (%)	WUE (kg $ha\text{-}mm^{-1}$)
Rainfed (Control)	1218	2135	-	36.32	-
Flower initiation	1454	2510	200	36.67	7.27
Pod development	1751	2969	200	36.84	8.75

Flower initiation and Pod development	2076	3498	400	37.04	5.19
S.Em ±	42.05	76.48	-	0.035	-
C.D. at 5%	123.3	224.27	-	0.102	-

A study reported that yield, water applied, harvest index and water use efficiency studies as influenced by irrigation stages of pigeonpea , Among the treatments irrigating at pod development stage has recorded higher WUE (8.75 kg ha-mm^{-1}) compared to the irrigating at flower initiation stage with WUE (7.27 kg ha-mm^{-1}) and at both stage that is at flower initiation and pod development with WUE (5.19 kg ha-mm^{-1}). Because irrigating at critical stage of crop (flower initiation and pod development) gives higher significant yield (2076 kg ha^{-1}), However the amount of water required in irrigating at two stage was higher than at single at single stage which resulted in decrease water use efficiency when irrigated at two critical stage but it was compensated by increased yield under irrigating at two stage that is flower initiation and pod development compared to irrigating at single critical stage (Ganesh, 2017) and results are in accordance with work done by (Ramah, 2021).

2.5 Fertilization

To increase water use efficiency and yield of pulses, the following fertilization requirements should be considered:

1. Soil Testing: Before applying any fertilizers, it is important to conduct a soil test to determine the nutrient requirements of the crop. This helps in applying the right amount of fertilizers, avoiding over-fertilization, and reducing the risk of soil degradation.
2. Nitrogen Fertilization: Pulses are nitrogen-fixing crops and therefore require less nitrogen fertilizer compared to other crops. However, they still require some amount of nitrogen to maximize yield and water use efficiency.
3. Phosphorus Fertilization: Phosphorus is an essential nutrient for pulses and is required for seed germination, root growth, and flower and seed production.
4. Potassium Fertilization: Potassium is important for regulating water balance in plants, improving drought tolerance, and increasing yield and water use efficiency.
5. Micronutrient Fertilization: Micronutrients like iron, zinc, and boron are also important for pulse crop growth and development. Deficiencies in these nutrients can reduce yield and water use efficiency.

It is important to note that the specific fertilization requirements for pulses may vary based on soil type, climate, and crop variety. Therefore, it is best to consult with a local agronomist or extension service for specific recommendations.

Table 8: Effect of nutrient management on yield, water use efficiency and B:C ratio of pigeonpea

Treatments	Pigeonpea yield ($t\ ha^{-1}$)	WUE ($kg\ ha\text{-}mm^{-1}$)	B:C ratio
F_0 -Control	0.96	3.15	3.96
F_1-100% recommended dose of fertilizers (RDF)	1.35	4.38	4.68
F_2-50% RDF + 50% recommended dose of nitrogen (RDN)	1.37	4.51	4.50
F_3-100% RDF + 50% RDN	1.52	4.98	4.73
F_4-50% RDF + 100% RDN	1.41	4.54	4.26
F_5-100% RDF + 5 kg Zn ha^{-1}	1.37	4.44	4.75
F_6-50% RDF + 50% RDN + 5 kg Zn ha^{-1}	1.66	5.31	5.21
F_7-100% RDF + 50% RDN +5 kg Zn ha^{-1}	1.72	5.59	5.24
F_8-50% RDF + 100% RDN + 5 kg Zn ha^{-1}	1.69	5.49	4.92
S.Em ±	0.03	-	0.06
C.D. at 5%	0.08	-	0.18

A studies reported effect of nutrient management on yield, water use efficiency and B:C ratio of pigeonpea, among the treatments highest WUE of 5.59 kg ha-mm^{-1} in pigeonpea was registered under fertilization with 100 per cent recommended dose of fertilizers + 50 percent recommended dose of nitrogen + 5 kg Zinc ha^{-1} compared to other treatments. Because of the physiological role of these nutrients such as nitrogen which is integral part of chlorophyll-primary absorber of light energy as this 50 per cent additional nitrogen increased photosynthesis and boosted the yield of crop, Zinc is constituent of various enzymes which play important role in increasing the metabolic activities of crop as a result, has increased the yield and water use efficiency. And fertilization with recommended dose of fertilizer will help to meet the plant nutrient requirement which resulted in good yield (Kumawat et al., 2013) .

2.6 Moisture conservation and reducing water loss

Soil moisture conservation is to minimize the amount of water lost from the soils through evaporation (water loss directly from the soil) and transpiration (water loss occurring through the plants) – or combined, the evapotranspiration. Preserving soil moisture is important means to maintain the necessary water for agricultural production, and also helps minimize irrigation needs of the crops.

There are several methods to conserve moisture and reduce water loss in pulses to increase yield:

1. Mulching: Covering the soil surface with organic matter such as straw or grass can reduce evaporation and conserve soil moisture (Megharani *et.al.* 2020).
2. Irrigation Management: Proper irrigation management techniques like trickle irrigation and drought can be used to conserve water and reduce wastage.
3. Crop Rotation: Growing pulses in rotation with crops that have deep roots can help to conserve moisture and improve soil structure (Rao *et al.*, 2018).
4. Row covers: Using row covers can reduce water loss due to evaporation and wind, especially in the early stages of growth.
5. Drought Tolerant Varieties: Planting drought-tolerant pulse varieties can help to conserve soil moisture and reduce the need for irrigation.
6. Soil amendment: Improving soil structure by adding organic matter can increase water retention and reduce runoff.
7. Reduced tillage: Minimal disturbance of the soil through reduced tillage can help to conserve soil moisture.
8. Reducing the water losses can increase crop water use for increasing the productivity and ultimely water use efficiency. Antitranspirants are use to reduce transpiration, selecting the best antitrasnspirants will reduce excess loss of water and help to get higher yield (Moghaddam *et. al.* 2017).

Table 9: Effect of transpiration suppressants on consumptive use (CU), WUE, moisture use rate and economics of pigeonpea

Treatments		Moisture use indices			Economics		
		CU (mm)	**WUE (kg ha-mm^{-1})**	**Moisture use rate (mm day $^{-1}$)**	**Cost of cultivation (Rs. ha^{-1})**	**Net returns (Rs. ha^{-1})**	**B: C ratio**
Transpiration suppressants							
T_0	Control	364.78	7.94	2.93	11300	28360	2.50
T_1	Cycocel (200 ppm)	391.54	8.10	3.11	11970	29760	2.48
T_2	PMA (320 ppm)	394.71	8.23	3.18	12000	30320	2.52
S.Em ±		3.82	-	0.04			
C.D. at 5%		11.41	-	0.12			

A research study reported the effect of transpiration suppressants on consumptive use (CU), WUE, moisture use rate and economics of pigeonpea. Among the higher WUE in pigeonpea was recorded with phenyl mercuric acetate (PMA) at 320 ppm spray (8.23 kg ha-mm^{-1}) followed by cycocel at 200 ppm spray (8.1 kg ha-mm^{-1}) and lower with control (7.94 kg ha-mm^{-1}). Because phenyl mercuric acetate is a stomata closing type antitranparent which reduce excess loss of water from the plant surface and increase the water use efficiency of crop, however cost of cultivation was low under control (11300 Rs. ha^{-1}) compared to PMA application (12000 Rs. ha^{-1}) but it was compensated by higher yield and water use efficiency under PMA treatment (Ansari and Rana, 2012) and result are in accordance with work done by (Vijayalakshmi and Rajagopal., 1995) .

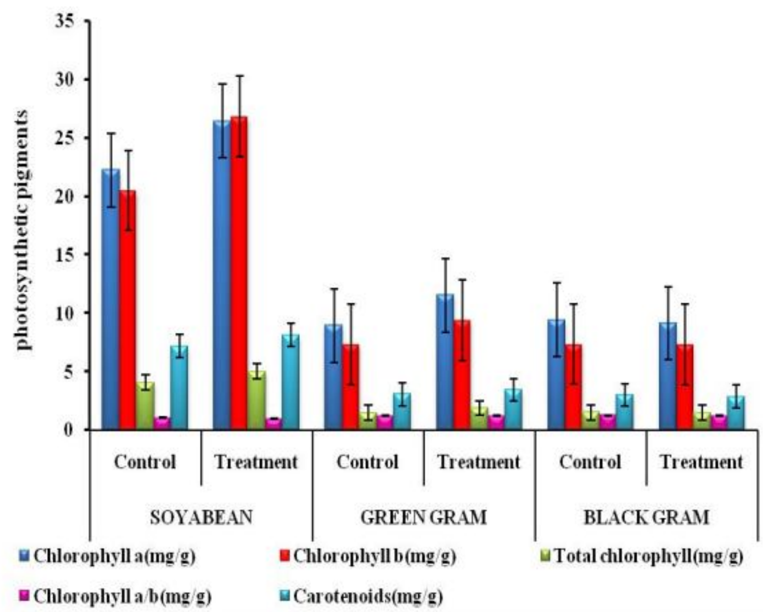

Fig1: Effects of exogenous application of ABA on the levels of various photosynthetic pigments in major pulses of Tamil Nadu

The results of the present study show that ABA has altered the stomatal behavior as a signal participating in the opening and closing mechanism of the stomata. Results obtained in present study show that all the pulses taken for the study show the expected response in terms of decrease in stomatal conductance and from the present study it is evident that the exogenous application of ABA not only regulates the stomatal movements but also cause variations in pigment compositions as a result of that it enhances the water use efficiency (Vijayalakshmi *et. al.*, 2014)

2.7 Weed management

Weed management can increase water use efficiency and yield of pulse crops by several methods:

1. Mechanical control: Regular cultivation, hoeing or hand weeding can reduce weed populations and competition for water and nutrients.
2. Crop rotation: Growing crops in rotation with different life cycles can reduce the weed seed bank and minimize weed pressure in pulse fields.
3. Cover crops: Using cover crops to shade the soil surface and reduce weed emergence can help conserve water and improve yield.
4. Herbicides: Application of selective herbicides can control weeds without damaging the crop. It is important to carefully follow label instructions and choose herbicides that are compatible with the pulse crop being grown.
5. Mulching: Applying organic mulch to the soil surface can reduce weed emergence and conserve soil moisture.

Implementing a combination of these methods can provide effective weed management and improve water use efficiency and yield of pulse crops (Yadav *et al.*, 2019).

Table 10: Seed yield, stalk yield, weed index, harvest index and WUE of pigeonpea as influenced by different weed control treatments

Treatments	**Seed yield (kg ha^{-1})**	**Weed Index (%)**	**WUE (kg ha^{-} mm^{-1})**
T_1: Hand weeding twice at 25 and 50 days after sowing (DAS)	884	38.50	2.9
T_2: Pendimethalin @ 0.75 kg a.i. ha^{-1} as a pre- emergence	825	42.60	2.7
T_3: Pendimethalin @ 0.75 kg. a.i. ha^{-1} + one hand weeding at 50 DAS	1281	10.90	4.2
T_4: Imazethapyr @ 75 g a.i ha^{-1} at 15-20 DAS	435	69.70	1.4
T_5: Pendimethalin @ 0.75 kg a.i. ha^{-1} + Paraquat @ 0.40 kg. a.i. ha^{-1} at 6 WAS	1250	12.90	3.9
T_6: Imazethapyr @ 75 g a.i ha^{-1} + Paraquat @ 0.40 kg. a.i. ha^{-1} at 6 WAS	540	62.40	1.8
T_7: Pendimethalin @ 0.75 kg a.i. ha^{-1} + Paraquat @ 0.40 kg. a.i. ha^{-1} at 8 WAS	1112	22.90	3.7
$T_{8:}$ Imazethapyr @ 75 g a.i ha^{-1} + Paraquat @ 0.40 kg .a.i.ha^{-1} at 8 WAS	514	64.20	1.7
$T_{9:}$ Alachlor @ 1.0 kg a.i. ha^{-1} as a pre-emergence	815	43.30	2.7
T_{10}: Alachlor @ 1.0 kg a.i. ha^{-1} + One hand weeding at 50 DAS	1270	11.50	4.1

T_{11}: weedy check	105	92.70	0.3
T_{12}: weed free plot	1438	0.00	4.7
S. Em ±	44	3.02	-
C. D. at 5%	128	8.85	-

Venkatareddy, 2011 reported seed yield, stalk yield, weed index, harvest index and WUE of pigeonpea as influenced by different weed control treatments. Among the treatments pre- emergent application of Pendimethalin @ 0.75 kg. a.i. ha^{-1} with one hand weeding at 50 DAS has recorded higher significant yield (1281 kg ha^{-1}) and water use efficiency (4.2 kg ha-mm^{-1}) compared to other treatments. This is because as pre-emergent application Pendimethalin performed well in controlling weed, and even as critical period of crop-weed competition for redgram is 25-50 days after sowing and hand weeding at that stage has reduced the competition and increased yield of crop and ultimetley increasing the water use efficiency of crop.

2.8 Pest management

Integrated Pest Management (IPM) practices can help increase water use efficiency and yield of pulse crops. This can be achieved through the following steps:

1. Crop rotation: Alternating pulse crops with non-host crops can reduce the buildup of pest populations.
2. Monitoring: Regularly monitoring crops for signs of pest infestation can help detect and manage infestations before they cause significant damage.
3. Cultural practices: Proper crop management practices such as appropriate planting and harvesting times, adequate soil fertility, and proper irrigation can help reduce the susceptibility of crops to pests.
4. Biological control: Encouraging natural predators and parasites of pests can help reduce pest populations.
5. Chemical control: If necessary, targeted and judicious use of pesticides can help control pest populations.

By implementing these IPM practices, farmers can reduce their dependence on pesticides, conserve water resources, and improve the yield and quality of their pulse crops.

❖ Conclusion

Optimizing water utilization can greatly enhance pulse production by reducing water waste, improving soil health and plant growth, and increasing yields. This can be achieved through various means such as drip irrigation, mulching, rainwater harvesting, soil moisture management, and the use of drought-resistant crop varieties. By using these strategies, farmers can conserve water resources, reduce costs, and enhance the sustainability and profitability of their pulse crop production.

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