REVIEW ARTICLE

Role of Pulses in Cropping Systems: A Review

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Abstract

Climate change threatens global food and economic security. The decreased availability and import of pulses highlight the urgency of increased production. Pulse included cropping systems are the only way to enhance production as the area available are limited. Increased yield at spatial and temporal dimensions are focused here. Cropping system, including pulses consists of intercropping, sequential cropping, mixed cropping, relay cropping, and *paira/utera* cropping. They compete for light, space, residual moisture content and available nutrients with companion crops. They improve soil properties, reduce pest and disease incidence. The specific role of pulses in the cropping system includes high carbon sequestration capacity, low carbon footprint, fixing atmospheric nitrogen in soils, low water footprint, hydrogen fertilization of soils and improving soil biodiversity. Since they are easy to cultivate it creates employment opportunities for women. Pulses provide economic profitability to farmers. There lies a promising, sustainable and cost-effective solution in these tiniest seeds.

Keywords: Climate change, Cropping system, Pulse, Inter cropping, Sequential cropping

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Introduction

Our world faces climate change in a manner so intense than the yester years, which makes the planet unfit for life day by day. Globally more than eight hundred million people are suffering from severe hunger and malnutrition (WHO, 2018). Climate change, population explosion, food insecurity, and associated risks directly influencing the economic systems of underdeveloped and developing countries where agriculture contributes a considerable share to the economy. The world looks for a solution to this situation in a sustainable manner. The solution should be cheap, easy to access, requires minimum input, moisture, care, and management practices and having a high nutritive content. Pulses are the best answer to all these requirements as it fulfills the criteria above mentioned. World Health Organisation recommends 80 g pulses man^{-1} day^{-1} (Pathak *et al*., 2017). The Indian Council of Medical Research (ICMR) recommends 40 g pulses man^{-1} day^{-1} (ICMR-NIN, 2011). However, actual availability ranges from 30 – 35 g pulses man^{-1} day^{-1} (Roy *et al*., 2017). In 2016, the Food and Agriculture Organization (FAO) brought pulses into the spotlight that has immense potential to address the issues of sustainability.

Pulses are an integral part of Indian life. It is a traditional offering in many temples. e.g., Green gram powder as *prasada* in Mookambika Temple, boiled cowpea in Parassini Muthappan Temple and *'chana sundal', a special preparation* during *Ganesh Puja*. Pulses are very good sources of protein. It also has qualities like low glycemic index (FAO, 2016), gluten free and even acts as a functional food (Rao, 2002). As pulses have a low glycemic index, they can be included in the diet of Type 2 diabetes patients. Pulses are so gluten-free that including it in diet will not cause chances of Celiac disease. Pulses are included in the list of functional foods. Food that claims to improve health or well-being by providing benefit beyond that of the traditional nutrients it contains is a functional food.

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Pulses are an important component of diets in many countries and can help to provide balanced nutrition. They can also be grown as a palatable and nutritious feed for animals, as green manure crop, a fuel source, or even for medicinal use. Pulses are efficient protein producers from the minimum of resources (Havlin *et al*., 2014). They act as a good fodder crop. Due to its drought-tolerant properties, it can be grown on marginal and wastelands. It even finds a suitable crop of summer fallows of cereals and areas where rain fed agriculture is practiced. It has a comparatively short duration than other crops, so it can fit into the gap between two main crops. It fixes atmospheric nitrogen efficiently through its root nodules. Thus, it not only reduces the fertilizer input of it but also reduces the fertilizer input of the succeeding crop to the extent of 25–30% (Smil, 1999; Garg and Geetanjali, 2007). It is also a good green manuring crop. Thus, it enhances the physical, chemical and biological properties of the soil. As it requires less input, less management practices and less labor requirements, the cost of cultivation of pulses is very less.

Pulses also play a key role in soil and water conservation. They are important crops for food security, combating malnutrition, alleviating poverty, improving human health and enhancing agricultural sustainability. Despite its importance to man, pulses are usually regarded as 'orphan crops'. 'Orphan crops' are crops that are not part of main crops that are traded internationally and often considered staple crops, such as rice, wheat or maize. However, the Food and Agriculture Organization of UN (FAO) identified these orphan crops as a solution to global food system risks and an investment opportunity for future agricultural research (GPC, 2016).

Need for cropping systems

Increasing the cultivable area and crop productivity are the general ways to increase production. As the population increases rapidly, the resources are depleted; hence, these considerations are less important. We should focus on cropping system approach for increasing pulse production per unit time and space (Reddy and Reddy, 2013). The prominent cropping systems in which pulses are included are intercropping, cropping sequence and *paira/utera* cultivation. The main cropping systems under inter cropping where pulses are cultivated are mixed inter cropping (homesteads), row inter cropping (Maize + Green gram), relay intercropping (green gram followed by maize followed by potato followed by wheat). The prominent sequential cropping system in which pulses are included are double cropping, triple cropping. *Paira/utera* cultivation is actually practiced to use the residual moisture left by the preceding crop (Palaniappan and Sivaraman, 1996).

Cropping systems involving pulses in India

The cropping systems of each area differ with other due to difference in rainfall, humidity, soil type, climate, etc. The main agro-climatic zones were cropping systems including pulses were followed include north and northwestern, central, eastern, and southern regions (Table 1, Table 2). Pulses are so versatile that makes it suitable with different types of crops (Panda, 2006).

Table 1: Major Cropping sequences involving pulses in India (Panda, 2006)

	Cropping system	
Region	*Kharif*	*Rabi*
North and North Western Region	Rice / Maize/ Sorghum Mung bean/ Urd bean	Wheat Chickpea Mustard
Eastern Region	Rice/ Pearl Millet/ Maize	Chickpea Horse gram/ Pigeon pea
Central Region	Sorghum/ Pearl millet Urd bean/ Moong bean/ Cowpea	Chickpea Wheat/ Sorghum
Southern Region	Rice Mung bean/ Cowpea	Sorghum/ Sunflower/ Finger millet Mung bean/ Urd bean/ Cowpea

Interactions in sequential cropping system

The interaction due to different crops in a sequential cropping system occurs on resources like soil, residual moisture, light, nutrients. The crops efficiently utilize the nutrients and moisture left over by the previous crop. They efficiently utilize the light as they cover the land very quickly due to change in growing and rooting pattern (Singh *et al*., 2009). The organic carbon content (Figure 1) and available soil nitrogen content (Figure 2) were found to be higher in those cropping systems (rice-rice-green gram, rice-rice-sesame, rice-rice-onion, maize-rice-sesame and groundnut- rice-black gram) in which pulses are included (Porpavai *et al*., 2011). The physical properties (Table 3) and chemicals properties (Table 4) tends to improve when pulses were included in a system (Prakash *et al*., 2008).

Interactions in inter cropping system

The interaction due to different crops in an intercropping system occurs on resources like soil, residual moisture, light, and nutrients. The crops efficiently utilize these resources due to the change in growth and rooting pattern. When maize and green gram are intercropped together, they have the least competition between each other due to the differences in a time period of peak requirement of resources. So the system as a whole will have benefits like weed smothering efficiency, reduction in disease, and pest incidence. The intercropping system will enhance the yield, test weight, and available nitrogen content after harvest and reduces the weed growth (Figure 3) in the system (Bridgit *et al.,* 1994). Rajeshkumar (2017) also reported the weed smothering efficiency of pulses in the intercropping system (Figure 4). They also found to reduce the incidence of pest (Uzokwe *et al.,* 2016) and diseases (5, Figure 6) (Schoeny *et al.,* 2010).

Specific role of pulses in cropping system

The key to the present climate problems is sustainable agriculture. Sustainable food production will feed all the

Table 2: Major inter cropping system involving pulses in India (Panda, 2006)

Region	*Inter cropping system*
North and north western region	Pearl millet/cotton + green gram Maize + cowpea/ black gram/ pigeon pea safflower + cowpea
Eastern region	Maize/ finger millet/ sorghum + pigeon pea
Central region	Groundnut + pigeon pea Pearl millet/ sorghum/ cotton + green gram Sorghum + black gram/ cowpea
Southern region	Pearl millet/ finger millet/ sorghum/ Groundnut + pigeon pea Tapioca + Cowpea/ horse gram

Figure 1

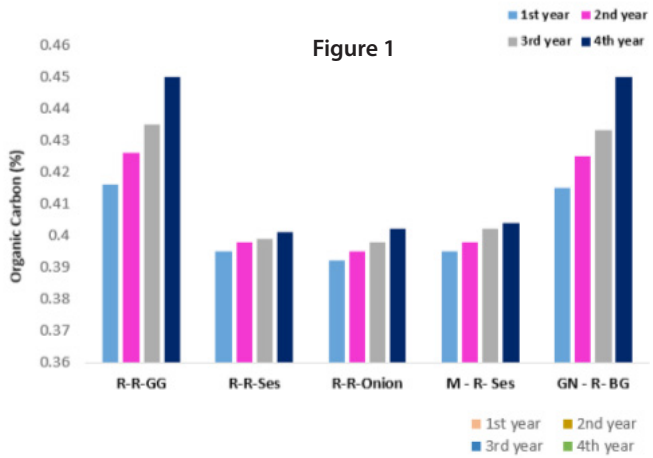


Figure 2

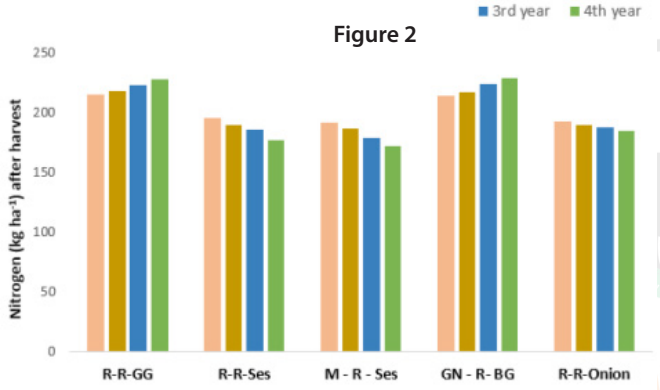


Figure1 and 2: Figure 1. Ddepicts the soil organic carbon content and Fig, 2. depicts the nitrogen content in soil after harvest in rice-rice-green gram, rice-rice-sesame, rice-rice-onion, maize-rice-sesame and groundnut- rice-black gram cropping systems.

Table 3: Effect of soil physical properties on cropping systems (Prakash *et al.*, 2008)

	Physical Properties		
Cropping systems	*BD(gm/cc)*	*Porosity (%)*	*WHC(%)*
Rice-Rice	1.67	26.50	21.20
Rice-Field bean	1.35	35.30	30.30
Rice-Cowpea	1.35	35.20	30.10
Rice-Green gram	1.38	29.80	28.90
Rice-Black gram	1.38	30.00	29.00

Table 4: Effect of soil chemical properties on cropping systems (Prakash *et al.*, 2008)

	Chemical properties		
Cropping systems	*pH*	*OC(%)*	*CEC(Cmol (p+)/kg)*
Rice-Rice	5.50	0.32	9.60
Rice-Fieldbean	6.20	0.56	10.50
Rice-Cowpea	6.23	0.55	10.24
Rice-Green gram	6.25	0.56	10.10
Rice-Black gram	6.24	0.54	10.20

Figure 3

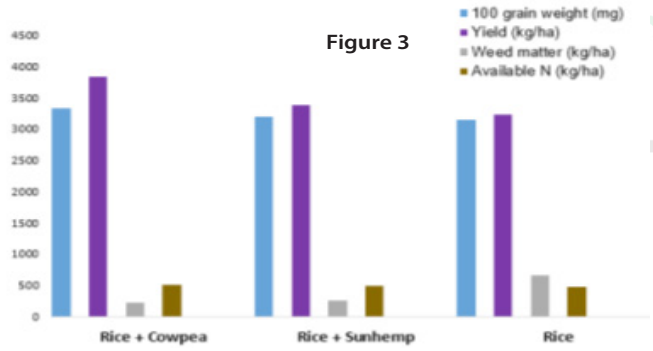


Figure 4

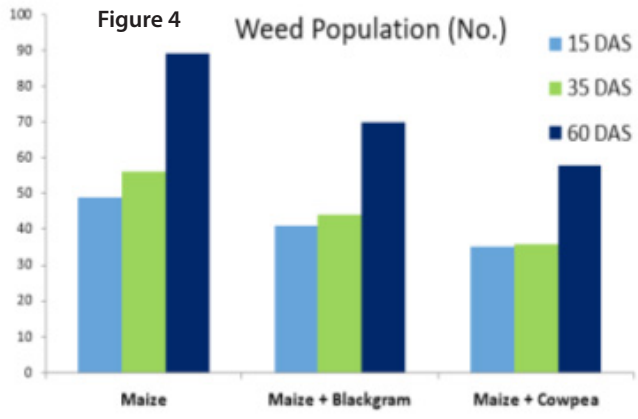


Figure 5

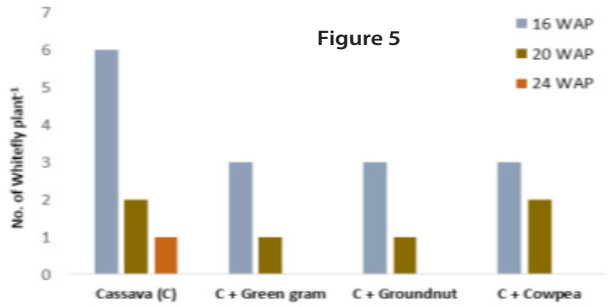


Figure 6

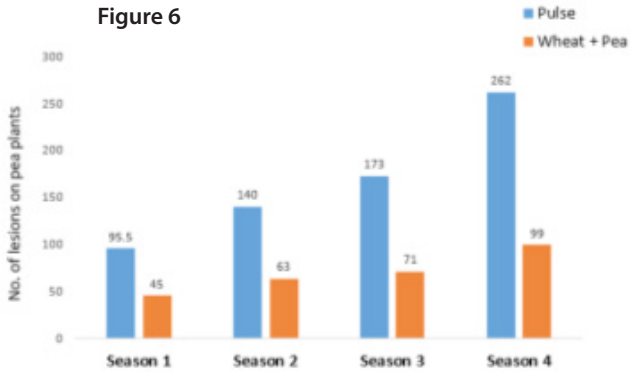


Figure 3-6: The inter cropping system will enhance the yield, test weight and available nitrogen content after harvest and reduces the weed growth (Figure 3.) in the system and weed smothering efficiency of pulses in inter cropping system is shown in Figure 4. The pest and disease control property of pulse in a system is de[icted by Figure 5 and Figure 6 respectively.

hunger and the malnutrition cost-effectively. Sustainability is the ability to continue a defined behavior indefinitely (WCED, 1987).

High carbon sequestration capacity

Cropping systems with pulses have more exceptional soil carbon sequestration ability than monocropping systems (FAO, 2016). Venkatesh *et al.* (2013) studied the effect of pulses and nutrient management on soil carbon sequestration (Table 5).

Low carbon footprint

Pulses have low carbon footprint in production than most animal sources of protein (FAO, 2016). Gan *et al*., (2011) reported that pulses decrease the carbon footprint (Table 6) of crop rotations. Pulses indirectly reduce greenhouse gas emission, when included in livestock feed, due to increased food conversion ratio while decreasing methane emissions from ruminants (Martin *et al.,* 2010).

Low water footprint

Pulses require the least amount of water for producing protein. Pulses consume only 19 liters of water to produce 1g of protein. Pulses require very less water for production as well as for processing when compared to the animal sources of protein, and this results in a reduction in the water footprint. Thus, pulses efficiently use the residual moisture content in the soil, and therefore it produces an excellent protein source from the minimum resources.

Nitrogen transfer in legumes

Nitrogen fixed by the legumes not only benefits the crop itself but it also benefits the crop in succession through legume effect and the companion crop grown with it (Figure 7). The N fixed is transferred through direct transfer through mycorrhizal hyphae, degradation of dead legume tissues followed by uptake by the crop and nitrogen as legume cell exudates (Paynel *et al*., 2008). In brief, pulses are climate-smart and hardy crops since they adapt to climate change. Pulses need fewer external inputs, reduce soil erosion and help in lowering greenhouse gas emission (FAO, 2016).

Table 5: Effect of cropping systems on total organic carbon (Venkatesh *et al.*, 2013)

Cropping system	*Total organic carbon (Mg ha^{-1})*
Maize- wheat	25.37
Maize-Wheat-Maize-Chickpea	27.47
Maize-Wheat-Mungbean	28.29
Pigeon pea-Wheat	27.91

Table 6: Carbon footprint of cropping systems (Gan *et al.*, 2011)

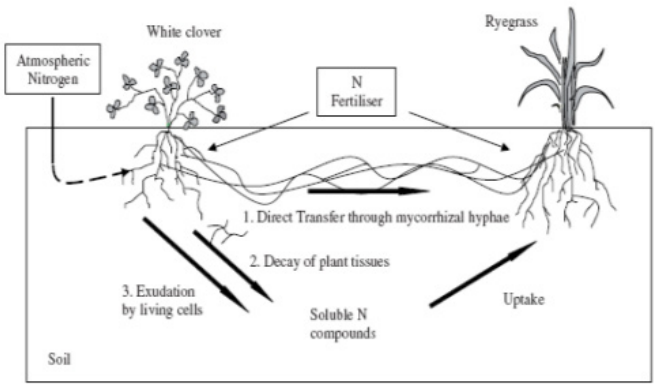
Cropping system	*CO_2kg^{-1} of grain (kg)*	*Percentage reduction*
Cereal - Wheat	0.42	0
Oilseed - Wheat	0.34	-19
Pulse - Wheat	0.30	-28

Improve whole-farm biodiversity

Pulses, because of their shorter duration fit well in different cropping systems, namely intercropping, crop rotation, and agroforestry as in floor crop in plantations in Kerala (Varughese *et al*., 2014). Increasing species diversity results in more efficient use of light, water and nutrients. It increases yields and lowers risk of crop failure (FAO, 2016). Cropping systems permit greater root utilization efficiency (Li *et al*., 2006) and provide groundwater to companion crops (Sekiya and Yano, 2004).

Improvement of soil biodiversity

Soil biodiversity mainly related to the microbial population in soil. Venkatesh *et al.,* (2013) reported the soil dehydrogenase activity under different cropping systems and the highest dehydrogenase activity was observed in the system containing pulse crops in Utah (Skujins, 1973). Dehydrogenase activity of soil is directly related to soil biological activity (Figure 8) (Skujins, 1973). Plant residues of pulses have narrow C: N ratio, which helps in easy decomposition. Root exudates are another key factor influencing microbial association in the legume rhizosphere (Table 9). Root exudates contain amino acids, sugars and carboxylic acids, which act as attractants for beneficial microorganisms (Sugiyama and Yazaki, 2012). Canavanine, an analog of arginine, is present



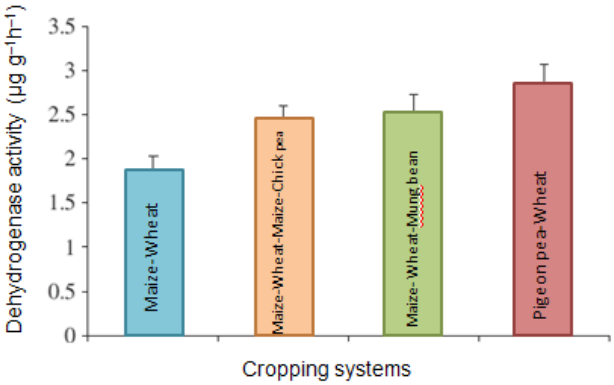


Figure 7 and 8: Fate of nitrogen fixed by the legumes is shown in Figure 7. Dehydrogenase activity of soil is directly related to soil biological activity as evident from Figure 8.

in high concentrations in legumes (Rodgers and Shiozawa, 2008). Rhizospheral bacterial population is optimized by canavanine in legumes to promote symbiotic interactions (Cai *et al*., 2009). Strigolactones released from the root exudates promote colonization of arbuscular mycorrhizal fungi (AMF) (Figure 10). Strigolactones are a group of apocarotenoids, which stimulates hyphal branching of AMF (Sugiyama and Yazaki, 2012).

Hydrogen fertilization

Pulses release hydrogen gas into soil as a byproduct of nitrogen fixation ($N_2 + 8\,H^+ + 8\,e^- \rightarrow 2\,NH_3 + H_2$). H_2 lost from nodules is oxidized by the soil in rhizosphere. Soils exposed to H_2 gas at a rate and duration similar to that from legume nodules, the fertility of the soil was enhanced in comparison with soil treated with air. Legumes fix 200 kg N $ha^{-1}$and produce about 2, 40,000 L hydrogen (Uratsu, 1983). Increased growth response of plants rotated with legumes included cropping systems due to increased bacterial populations adjacent to H releasing nodules (Dong *et al*., 2003).

Pulses for food and nutritional security

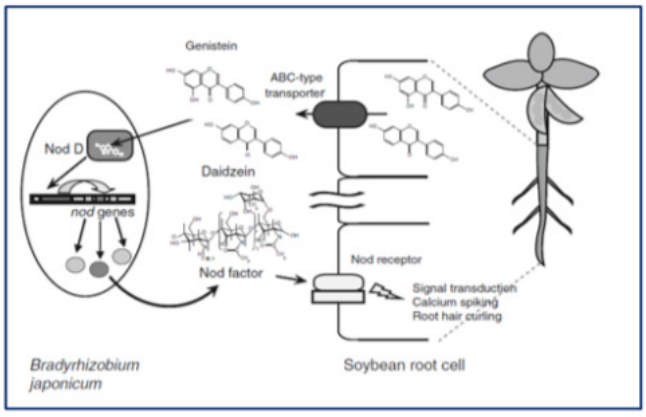
Pulses are affordable source of protein and minerals for poor (FAO, 2016). They are having low food wastage footprint and can be stored for long periods without losing their nutritional value. Pulses were recognized as super food of 2016. It has been considered as future food and a nutritional powerhouse in diet. Pulses have twice the amount of protein found in cereals (Table 8). Their nutrient content makes pulses ideal for vegetarians (NIN, 2004). Inclusion of pulses in fast foods like pasta, burger, spaghetti etc. improves the acceptability of pulses among new generation. Moreover, the rising conscious preference toward vegetarian diet over non-vegetarian, pulses are likely to be more valued commodities in the civilized society (FAO, 2016).

Gender equity in pulse production

Gender aspect of pulse production relates women participation in the value chain of pulses *viz.* commercial pulse production, processing, marketing and ultimately to feed families (FAO, 2016). Pulses require less labor compared to other crops. Therefore, women can participate in cultivation activities with men (Figure 11, 12). Thus, they earn themselves and start to support their family. So, pulses act as good tools of teaching women empowerment, gender equality and dignity of labor to illiterate farmers. Women found to have surpassed men in on farm and post-harvest activities in pulse production (Sah, 2013).

Pulses for economic sustainability

Pulses contribute to economic sustainability as it ensures farmer's sustainable income. Inclusion of pulse crops in the cropping system improves the economic sustainability of resource-poor farmers. It ensures an extra profit from pulses



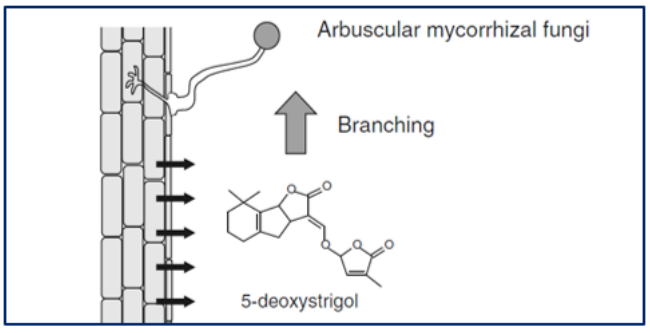
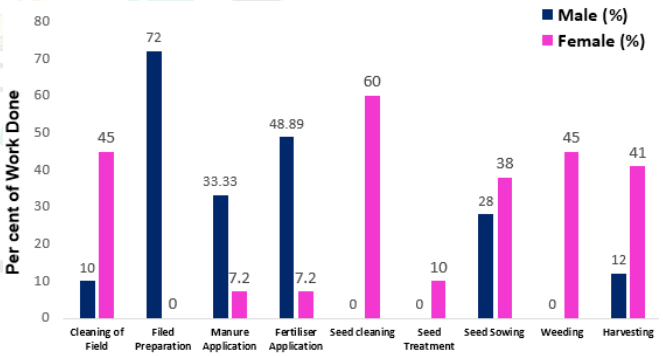


Figure 9 and10: Figure 9 shows how root exudates influence microbial association in the legume rhizosphere. Strigolactones released from the root exudates promote colonization of arbuscular mycorrhizal fungi depicted in Figure 10.



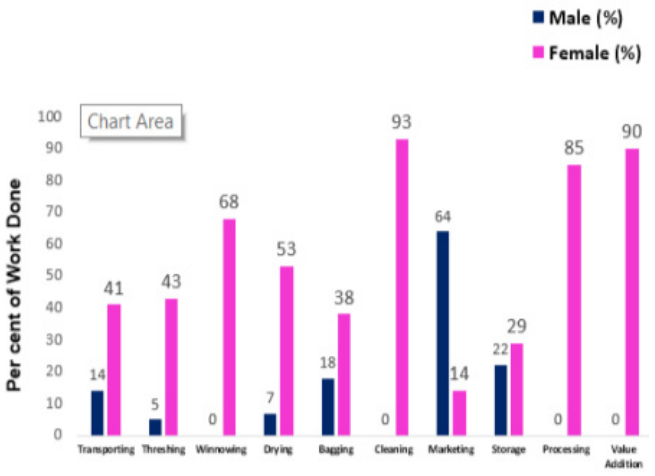


Figure 11 and 12: Figure 9 and Figure 10 show per cent of pulse cultivation carried out by women.

Table 7: Nitrogen fixed by cultivated legumes (Havlin, 2014)

Sl. No.	*Crop*	*Nitrogen fixed (kg ha-1)*
1	Peas	50–130
2	Lentil	40–130
3	Soybean	20–260
4	Black gram	80–140
5	Chick pea	20–100
6	Green gram	30–60
7	Cowpea	60–120
8	Pigeon pea	140–220

Table 8: Nutritional value of pulses: a comparison with cereals (Source: NIN, 2004)

Food crop	*Energy (k Cal)*	*Protein (g)*	*Fat (g)*	*Fibre (g)*	*Minerals (g)*
Raw milled rice	362	6.8	0.5	1.0	0.6
Wheat	348	11.8	1.5	2.0	1.5
Chick pea/ Gram	360	17.1	5.3	3.0	3.0
Cowpea	323	24	1.0	3.8	3.2
Red gram	335	22.3	1.7	3.5	3.5

Table 9: Economics of rice based cropping systems (PDCSR, 2005)

Treatment			*Yield (kg ha^{-1})*			*Total returns(₹. ha^{-1})*
I season	*II season*	*III season*	*I season*	*II season*	*III season*	
Rice	Rice	Fallow	4146	3747	-	46564
Rice	Rice	Cowpea(green manure)	4358	3933	-	48917
Rice	Rice	Cowpea (grain)	4518	3959	1213	74273

in the conventional cereal- fallow rotation, and it ensures a higher yield of subsequent crops (FAO, 2016). Pulses reduce the cost of cultivation since they use half the non-renewable energy than other crops (Smith *et al.,* 2008), and due to the adoption of good management practices. Increased farm labor productivity can also be ensured from a good cropping system including pulses. Cropping system including pulses ensures food and nutritional security of farm family (FAO, 2016). A study conducted at Karamana, Kerala on rice-based cropping systems revealed that rice-rice-cowpea (grain type) system was found better (Table 9). Inclusion of summer legumes had a beneficial effect on the system yield (PDCSR, 2006). These specific roles of pulses in the cropping system are of greater importance, and thus it contributes to the cropping system productivity.

Conclusion

Sustainable efforts are needed to end hunger and provide food security. Pulses are efficient producers of proteins. They are relatively climate-hardy. Pulses contribute sustainability by mitigating and adapting climate change, reducing poverty and hunger, improving health by providing nutrition, and help to promote economic stability. Adaptability to fit into various cropping systems by introducing pulses into farm production can be a key to increase resilience to climate change. Pulses are good for people, good for soils and good for the planet.

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