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Agro-ecological Sustainability with Pulses under System of Crop Intensification: A Review

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ABSTRACT

Pulses, endowed with unique ability of nitrogen fixation constitute an important component of crop diversification and resource conservation in farming systems. System of crop intensification (SCI) is an agricultural production strategy that seeks to increase and optimize the benefits that can be derived from making better use of available resources: soil, water, seeds, nutrients, solar radiation and air. System of crop intensification practices enable the crop to grow and develop potentially which provides enhanced production in sustainable and eco-friendly manner. Therefore, classical crop cultivation practices need to overhaul by adopting system of crop intensification for more profitability and sustainability. It includes ecosystem services taking full account of the factors and interactions of time and space so that field operations are conducted in a timely way. System of crop intensification has emerged as a next generation agro-ecological innovation. System of crop intensification principles and practices build upon the productive potentials that derive from plants having larger, more efficient, longer lived root systems and from their symbiotic relationships with a more abundant, diverse and active soil biota. Adoption of system of crop intensification practices in pulses may enhance the productivity and ecological sustainability of the system and reduce the gap between per capita availability and consumption of pulses and also enhancing the resource use efficiency of the system.

Key words: Agro-ecological, Intensification, Pulses, Sustainability, System.

High input-based agriculture while giving short-term returns, damages soil health, eco-balance and agricultural sustainability in the long run. Thus, there is an urgent need to build soil-health systematically and to maintain it. It is important to increase the productivity and resilience of land resources. System of crop intensification is one of those practices which aim to improve the productivity, sustainability, food security and resilience to climate change by altering the traditional practices of crop, soil, water and nutrient management (IAASTD, 2009).

Principles of system of crop intensification (SCI) can be applied in various crops such as rice, wheat, pulses, sugarcane, mustard. System of crop intensification practices enable the crop to grow and develop potentially which provides enhanced production in sustainable and eco-friendly manner. Therefore, classical crop cultivation practices need to overhaul by adopting SCI for more profitability and sustainability.

Importance of pulses in agriculture systems

Pulses are basic for a sustainable crop production system endowed with unique ability of nitrogen fixation, which constitute an important component of crop diversification and resource conservation in farming systems. These crops not only fix the atmospheric nitrogen for their growth and thereby reducing the dependence on external nitrogen source, but also for their residual effect. They are rightly termed as mini nitrogen-factories (Singh, 2018). Pulses as a cover crop contribute significantly towards higher rates of accumulation of soil carbon than cereals or grasses and pulses inclusive crop rotations have a higher soil carbon (C) sequestration potential than that of monocrop systems.

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Crop intensification through cropping systems

In India rice-wheat cropping system (RWCS) occupies almost 10.5 million hectares and is contributing 75% to the national food basket. However, practicing intensive rice-wheat rotation over time leads to lower input use efficiencies, soil heath degradation, receding ground water table and declining factor productivity. Therefore, crop intensification in the existing system with lower input demanding crop such as pulses is needed for sustaining food security and minimizing over exploitation of natural resources. In India, pulse crop is grown under diversified agro-ecologies with reasonable external inputs and residual soil moisture. It provides multiple benefits such as better human nutrition, higher yield per hectare, increasing farm income, improves

resource use efficiency and restoring soil fertility through the addition of soil organic matter. As they are more biologically efficient and resource conservative sequences to cereals (Rai and Biswakarma, 2021).

The low farm inputs and operational requirement in rice-lathyrus and rice-lentil rotations led to higher economic returns and up-scale energy use efficiency, thus ensuring a sustainable approach of inclusion of these crops in rice fallows, where farmers, in general, have poor socio-economic status. Among the cropping systems, legume inclusive rotations, *i.e.* rice-lathyrus (1.84 kg/ha/year), rice-lentil (1.83 kg /ha/year) and rice-chickpea (1.84 kg/ha/year), had lower N_2O emission compared to oil seed inclusive rotations rice-mustard and rice-linseed of 2.15 kg/ha/year (Kumar *et al.,* 2019).

Sustainability of systems

Agriculture being climate dependent is highly vulnerable to weather variations. It is important to increase and diversify land-based income sources. Sustainable agriculture is not only about seed improvement, it is also about sustainable and practical methodologies. These methodologies have to be simple to follow, based on locally available and inexpensive inputs. They also have to be capable of being up-scaled, while being adaptable to local weather-and-soil conditions.

The sustainable improvement of agriculture productivity is an important aim of watershed organisation trust (WOTR, 2013), they have introduced SCI, a modification of successful SRI and applied it to a variety of crops.

Role of SCI

SCI has emerged as a next generation agroecological innovation. SCI principles and practices build upon the productive potentials that derive from plants having larger, more efficient, longer-lived root systems and from their symbiotic relationships with a more abundant, diverse and active soil biota. SCI is an agricultural production strategy that seeks to increase and optimize the benefits that can be derived from making better use of available resources: soil, water, seeds, nutrients, solar radiation and air. It includes ecosystem services taking full account of the factors and interactions of time and space so that field operations are conducted in a timely way (Garbach *et al*., 2017). SCI is a four prolonged approach that is implemented systematically, more so in the case of poor soils. It involves soil preparation and management, crop spacing, systematic application of locally prepared organic inputs and micro-nutrient foliar sprays.

Why SCI (WOTR, 2013)

Easy adoption

SCI is simple to understand and follow and can be practiced by all farmers. It also is a method that can work in any agroecological system. It thus can be widely applied across varied crops and ecosystems. SCI uses locally available, inexpensive, organic inputs and only initial use of micronutrient foliar spray and basal applications thus making it low input technique.

Viable intermediate to organic farming

Yields in low external input farming or organic farming increase gradually and actually give results after three years. SCI is thus highly suitable for poor farmers as the yields do not show a sudden decrease because initially small amounts of chemical micro-nutrients are used as fertilizers. Pesticide usage is also nil. Over three seasons, as the soil health improves, the usage of micro-nutrients tapers off and the farmer eventually practices pure organic farming without having to face the initial losses due to reduced yields.

Climate adaptive method

SCI method increases the plant's resilience and adaptive capacity. The plants are much bigger, healthier with stronger root system. They are able to withstand, strong winds and high intensity rainfall and endure much less damage. The plants also have higher tolerance to heat especially during the dry spells. Adequate amounts of phytochemicals in the plant's system help combat climate induced stresses such as pest attacks better. The application of the specially prepared organic fertilizers in the soil increases the capacity of the soil to hold moisture, due to which even with lesser water availability crop yields do not get much affected.

Use of botanicals

Extracts (3-5%) of *Tectona grandis, Calatropis procera, Ageratum conyzoides, Ocimum tenuiflorum, Physalis minima, Amaranthus tricolor, Parthenium hysteroporus and Calotropis gigantea* proved effective in several crops as compared to an untreated control, a weed free check and a synthetic herbicide. The botanicals showed better weed management than the control with an 1170% higher productivity in several crops (Bera *et al.,* 2012).

Through intercropping

A further element of intensification has been the intercropping of legumes such as lentil with wheat, replacing some rows of wheat with pulses. The soil benefits from nitrogen fixation done in the legume roots, while households can attain greater income and/or have a more diversified diet.

Intensification in rice fallows

Cultivation of early-maturing chickpea in rice fallows which hold sufficient post monsoon soil moisture has led to better resource utilisation. The improved pulse production technologies were highly profitable and net returns were between 130-400% with 30-100% higher grain yields than either nothing or over farmers' practices (Pande *et al.,* 2011).

Methodology of SCI

- Establish healthy plants both early and carefully, taking care to conserve and nurture their inherent potential for root growth and associated shoot growth.

- Reduce plant populations significantly, giving each plant more room to grow both above and below ground.
- Enrich the soil with decomposed organic matter, as much as possible, also keeping the soil well-aerated to support the better growth of roots and of beneficial soil biota.
- Apply water in ways that favour plant-root and soil-microbial growth, avoiding hypoxic soil conditions that adversely effected root growth and aerobic organisms (Abraham *et al*., 2014).

Application of SCI in pulses

The average yield and profitability enhanced by 56 and 67 per cent respectively, in pulses under SCI system (Behera *et al*., 2013).

Pigeon pea transplanting under system of intensification improved its productivity, wherein seedlings were raised in the polythene bags in nursery and transplanted in the main field. Raising pigeon pea seedlings and transplanting in the field later on receipt of good rains would help in reaping the benefits of early sowing with higher yield than direct seeding Praharaj *et al.* (2015). In pigeon pea nipping arrests the apical bud dominance and increases the production of side branches thus increase the canopy size, photosynthetic activity and more flower buds per plant leading to enhanced grain yield. Also, foliar application of 1% PPFM avoids moisture stress to the crop at critical crop growth stage in rainfed conditions (Ammaiyappan *et al.,* 2021).

Production and productivity of the crop is governed by environmental conditions, genotypic trait and management of the crop. Determining appropriate crop density is therefore the management activities which improves the performance and productivity of plants Shiferaw *et al.* (2018). System of chickpea intensification has been reported to produce higher seed yield of chickpea compared to conventional sowing method which may be attributed due to wider spacing and nipping practice (Sonboir *et al.,* 2019).

Amrutha *et al.* (2015) evaluated black gram with different spacing and found that spacing had a significant influence on days to 50 per cent flowering. In wider spacing of 60 cm × 10 cm, black gram flowered earlier (42.01 days) and matured earlier (74.81 days) than in closer spacing (30 cm × 10 cm). It might be related to better vegetative growth, plant canopy area and efficient photosynthetic activity which might have enhanced the reproductive phase in wider spacing compared to closer spacing.

Foliar application is another strategy under SCI, foliar spray of DAP 1% and jeevamruth 5% increased the seed yield and net profit in green gram Kulkarni *et al*. (2015). In cowpea, plant growth parameters like plant height (75.88 cm), fresh weight (260.70 g), dry weight (36.44 g) and number of leaves per plant (25.67) when treated with compost of rice straw Faiyad *et al.* (2019). Foliar application of phosphorous in the form of DAP eliminates fixation of insoluble triphosphates in soil. Generally, 2% foliar application of DAP is recommended to prevent flower drop and better seed set in green gram Sivakumar *et al*. (2019). Many experimental findings proved that foliar application of nutrients increased the growth, better utilization of nutrients, yield attributes and yield in different pulse crops (Yeshwanth, 2020).

Vekaria *et al.* (2012) reported that foliar nutrition with potassium nitrate in green gram showed promising effect on growth and yield and found as the most effective osmo protectants in compensating yield losses. Application of potassium seemed to overcome the adverse effects of salt stress and to improve the morphological parameters, yield and yield components of green gram grown under salt stress (Rahman *et al.* (2017). Bahadari *et al.* (2020) observed that three times foliar application of 2% urea at pre flowering, flowering, pod development stages (40, 50 and 60 DAS) was the most suitable treatment to get higher growth, productivity, profitability, production and monetary efficiency of green gram.

Planting pattern is an important factor determining individual crop plant performance. Spatial arrangement has been quantified as the mean rectangularity, or the ratio of distance between rows to the distance between plants within a row. The influence of rectangularity has been quantified by measuring mean population yield rather than individual plant yield within the population (Fanish and Raghavan, 2020).

Double seedlings per hill maintained at 40 cm × 40 cm recorded higher number of pods per hill, but it has no influence on grain yield in green gram Kuttimani and Velayudham (2016). Single seedling per hill maintained at 25 cm × 25 cm registered higher grain yield in green gram compared with other spacing. They also found that the maximum net returns and B:C ratio were observed under medium spacing (25 cm × 25 cm) with single seedling per hill (Sathiyavani *et al*., 2016).

SCI adaptations in soybean is achieved through practices of direct seeding, wider and regular spacing of 30 cm × 30 cm by sowing 1-2 seeds/hill, with two manual weedings and with application of PAM (Panchagavya, Amritghol and Matkakhad). The same was applicable for soybean and lentil (PSI, 2010).

Benefits of crop intensification

- Better utilization of natural resources which helps in ecological sustainability.
- Alternate crops may enhance profitability.
- Stabilized farm income and productivity.
- Better human nutrition and health.
- Reduced pest incidence (diseases, insects, weeds *etc*).
- Enhanced employment opportunities.
- Reduced crop failure risks in dry lands.

CONCLUSION

Adoption of system of crop intensification practices in pulses may enhance the productivity and ecological sustainability of the system and reduce the gap between per capita availability and consumption of pulses and also enhancing the resource use efficiency of the system.

Conflict of interest: None.

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