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Prospects of Cropping System and Nutrient Management Towards Sustainability in Agriculture: A Review

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ABSTRACT

Cropping system involves proper management of inputs in a synergistic manner. Latest advancements in cropping system has resulted in including new rewarding crops in an appropriate manner with higher efficiency in utilization of resources. This ultimately effects the farmers with higher gross returns. Considering this fact, proper cohesion of nutrients/resources is essential to maintain an optimum fertility in the soil. This involves precise integration of synthetic chemicals, organics and biofertilizers; so that these practices may not incur a deterioration in soil health. Thus, this review projects the techniques of efficient pre-requisites in a cropping system for achieving higher productivity in a eco-friendly manner.

Key words: Cropping system, Nutrient management, Soil health, Sustainable.

Cropping system is an important component of a farming system (Shaukat *et al.,* 2021) that represents a cropping pattern in a farm. This includes the interaction of farm resources, farm enterprises and technological interventions which determine their credibility (Tony *et al.,* 2020). Historical cultivational practices indulged in monocropping and continuous cropping of identical crops to feed the population. This is considered as a vulnerable way of production, due to the prevailing unprecident climatic factors. This will also lead to the development of new epidemic zones for pest infections in near future. Reinforcing these conditions; a more sustainable mode of producing food is vital to fulfil the needs of growing populations in limited arable lands. Therefore it has become necessary to increase the production of food grains by adopting intensive cropping system. Prospectives of intercropping has recently developed a means of utilizing a single season to produce more crops by optimizing the use of environmental resources.

This is a proven solution for increasing the total crop production per unit area of land (Lithourgidis *et al*., 2011). Nutrient management in cropping systems varies up of the soil from monocropping, as it requires careful consideration in terms of how much quantity of fertilizers is applied. This consists of evaluating the residual effect of previous cropping patterns. Legumes in this regard is advantageous in enriching the nutrient build of the land. Organic sources of nutrients applied to the preceding crop benefit the succeeding crop to considerable extent and therefore the system productivity becomes sustainable through integrated use of organic and inorganic sources of nutrients. Twenty to fifty percentage of inorganic nitrogen can be effectively substituted by green manure incorporation (Subramani *et al.,* 2005) which is also a key factor in sustainable production.

There have been several changes in cropping pattern in India and currently farmers opt towards crop diversification. Crop diversification in India is typically viewed as a shift from traditionally grown less remunerative crops to more remunerative crops. This acts as a powerful tool in minimizing the risks in farming (Chand and Chauhan, 2002). Among different cropping systems, pulse-based cropping systems are environmentally sustainable as it requires lower amount of fertilizers, pesticides and irrigation due to their mutualism which enhances the overall productivity by increasing the yield of subsequent crops (Reddy, 2009). The nitrogen fixed by rhizobium is released within the soil and this contributes to soil fertility. The fixed N can at least partly reduce the N fertilizer requirement in the field during crop rotation. The carryover effect of N for succeeding crops may be 60 to 120 kg/ha for berseem, 75 kg/ha for cluster bean, 35 to 60 kg/ha for fodder cowpea, 68 kg/ha for chickpea, 55 kg/ha for black gram, 54 to 58 kg/ha for groundnut and 36 to 42 kg/ha for pigeon pea (Ghosh *et al*., 2007). Thus including legumes and fodder legumes as preceding or intercrops is an efficient cropping system towards sustainability.

Now-a-days, inclusion of cereals, millets and oilseeds along with vegetables in cropping system is practiced to ensure food security (Reddy and Suresh, 2009). Vegetables are great choice of cash crops as they grow easily, produce

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good yields and generate higher price in markets compared to cereals (Singh *et al.,* 2013). The demand for vegetables is increasing per annum and there is a good scope for production and export of vegetables from India. Moreover, these vegetable crops are suitable for remuneration on small land holdings and their inclusion in traditional cropping systems might improve the nutritional value of the system as they are rich in vitamins, minerals and other health factors (Adekiya, 2019).

Though there are different cropping systems adopted by the farmers based on their experience, a scientific validation is required to advocate location specific cropping system to specific areas. Sustainable cropping system with new valuable crops would impart new challenges and opportunities and they reveal the possibility for land productivity with the efficient use of resources. Identification of appropriate crops in a system may help to realize more returns with maximum input use efficiency that is developed by cohesion among the resources applied (Tejeswara *et al.,* 2015). Bio-intensive diversified complementary cropping systems would enable small and marginal farmers to utilize limited land and water resources in more sustainable manner. Hence, it is imperative to design alternate cropping system based on soil and climatic resources in addition to social requirements of the people. With this, the present review focuses to update the knowledge on the production aspects of cropping system with sustainable nutrient management.

Production potential of cropping systems

Monocropping

Monocropping refers to growing of a single crop on a piece of land area year after year (Vishwanath and Talwar, 2017). In monocropping without sufficient fertility management, soil fertility deteriorates as the continuing crop cycles extract the nutrients from the soils. Also, continuous mono-cropping increases the disease susceptibility of a crop as a single pathogen has the potential to destroy an entire crop. Earlier conventional monocropping systems with multilines were a suitable choice to create a natural barrier against diseases in rice and wheat (Tilman *et al.,* 2002). This was benefiting the farmers who follow monocropping pattern.

Bearing in mind, the redgram system, sole redgram recorded significantly more plant height, dry matter production, primary and secondary branches compared to the intercropped redgram (Shanmugam, 2008). Similarly, Rao and Mathuva (2000) revealed that, the annual grain legume based cropping systems were 32 to 49 per cent more profitable than continuous sole maize, making them attractive to small farmers in semi-arid tropics.

Concordantly, the highest B:C ratio in potato was attained as sole crop and the lowest B:C ratio for maize was obtained as a sole crop. This states that maize could be opted for intercropping systems to avail a higher B:C ratio and similar reports for beneficial intercropping in maize with potato is reported by Prakash *et al.* (2004).

When rice was intercropped in different cropping systems, maximum net benefit (Rs. 42,325/ha) was recorded in rice + maize which was 37 per cent more than sole rice followed by rice + cowpea (Rs. 30,885/ha) which was 14 per cent higher than monocropping of rice (Rs. 26,526/ha) (Abdul *et al.,* 2010). When compared to monocropping of rice-fallow sequence in sandy loam soil, the maximum LUE of 64 per cent was observed in rice-brinjal followed by rice-groundnut (63 per cent) and rice-onion (63 per cent) which had given relatively lower yield due to its longer duration with less return (Samant, 2015).

Intercropping of sorghum with guinea grass sown simultaneously, yielded higher revenue (Rs. 91,572/ha), which was 2.4 times greater in revenue achieved by monocrop of sorghum (Rs. 38209/ha) (Borghi *et al.,* 2013). Intercropping of millets with pulses, such as finger millet with pigeon pea produced more yield under intercropping compared to grown as sole cropping (Maitra *et al.,* 2001). Parallel results for intercropping in finger millet was attained with bhendi followed by field bean, cluster bean and pigeon pea. Contrasting a low yield for intercropping with bajra, sorghum and groundnut was reported by Triveni *et al.* (2017). These studies suggest that both mono and intercropping are beneficial in their own way in different cropping systems. Hence, this provides a outline of framing a proper cropping system for each crop to attain a gross benefit in agriculture.

Double cropping

Double cropping, the growing of two crops on the same field in a year in sequence or mixed cropping, fits under the concept of sustainable agriculture. Double cropping returns more organic residues to the soil than single-cropping. Moreover by double cropping, land equivalent efficiency gets improved with full utilization of resources. The successful implementation of the double cropping programme is dependent on a higher use of inputs (Christopher *et al*., 2015).

In double cropping programme, maize intercropped with different cropping system provides a higher gross return (Rs. 49672/ha), net return (Rs. 32571/ha) and B:C ratio (1.91). Double crop of maize + lentil compared to sole maize was beneficial (Misra *et al.,* 2001). Also, intercropping of millets with pulses, sorghum + cowpea (2:2 row ratio) recorded significantly higher net return (Rs. 6804/ha) and B:C ratio (2.77) compared to sorghum alone (Sankaranarayanan *et al.,* 2005). In oilseed based intercropping system, mustard was intercropped with sugarcane and a complementary use of resources on both space and time was attained. However, sugarcane offered lower competition to mustard due to its slow initial growth and wider row spacing (Singh *et al.,* 2010).

According to Singh *et al.* (2009) higher land equivalent ratio (LER), area time equivalency ratio (ATER) and effective yield total (EYT) were obtained at mustard + chickpea (2:6 row ratio). Cotton was intercropped with pulse crop like blackgram, greengram, soybean and clusterbean. It was observed that the seed cotton yield was equivalently higher in intercropping system than sole cotton due to higher market price fetched for pulses (Ravindera *et al*., 2017).

Multiple/Sequential cropping

Sequential cropping of plants with relatively short growing seasons offers a better land usage efficiency than does one single crop system (Azam-Ali, 2003). This much enhanced when is particularly early maturing and high yielding varieties are used and this will increase the environmental biodiversity in other hand (Ganajaxi *et al.,* 2010). Intercropping increases production per unit area per unit time without affecting the production of main crop to a greater extent. Therefore, crop intensification will be in both time and space dimensions. Higher yield in terms of total biomass and grain production per unit area in a given season with minimum inputs under intercropping system is attributed for a better utilisation of all resources namely, nutrients, light and moisture (Wen *et al.,* 2020).

Multiple intensive cropping of cotton; lablab - sesamum - brinjal as well as maize - cowpea - tomato and beetroot - greengram - maize were also enumeratively higher yielding with higher B:C ratio (Kalpana *et al.,* 2009). Pooniya *et al.* (2017) stated that among different intensive cropping system, cowpea-potato-mungbean recorded higher than mungbean-equivalent-yield (MEY), net return, monetary efficiency. This also enhances the soil properties as it is considered suitable option for indo-gangetic plains. Followed the above cropping pattern, kharif onion-wheat- mungbean system was also efficiently viable for the farmers.

Nutrient management in cropping system

Nutrient recommendations for any cropping system is usually done based on individual crop requirements without considering the interactions of accompanying crops in a cropping systems. Here, to produce crops in a sustained way, different factors are to be taken into consideration and they are the nature of preceding crop, yield and residual effect of fertilizer application (Kumar *et al.,* 2000). This persuades the importance of planning proper dosage recommendations to variable cropping system.

Effect of different sources of nutrients on productivity of cropping systems

Farmyard manure (FYM) is the basic source incorporated in all systems. It is the decomposed material of cattle dung and urine and left over fodder and bedding material in the cattle shed. Its chemical and nutrient composition varies with the quality of substrate, ways of collection and handling. Singh and Chauhan (2002) stated that farmyard manure possessed 22.50 per cent organic carbon, 1.73 per cent nitrogen, 0.28 per cent phosphorus and 1.02 per cent potassium. However, it seems to serves as a potential source for both macronutrients and micronutrients.

Application of FYM, result in a long term fertility trial of rice - wheat cropping sequence had reported a higher yield with increase in available P (Ladha *et al.*, 2004). Likewise, a significant increase in available potassium content in soil was observed at the fourth year of regular application of FYM (44 mg/kg soil, compared with initial value (38 mg/kg soil). A report from Barik *et al.* (2006) stated that two years continuous application of FYM @ 10 t/ha resulted in significant increase in available nitrogen, P_2O_5 and K_2O (99.8, 62.6 and 71 kg/ha, respectively as compared to the unmanured condition. The availability of P can be increased if it is mixed with FYM (Nazim *et al.,* 2008).

Followingly, the continuous review of FYM states its major role in optimizing the soil pH and EC conditions. This optimization by lowering the soil pH and EC was reported by Nagar *et al.* (2016). This study provided the superiority of FYM with phosphocompost over pigeon pea stalk and also this presented the adverse effect of increase in soil pH and EC due to sole RDF application.

Among the diverse organic manures, vermicompost is another rich source for macro and micronutrients. Earthworm derived nitrogen could supply 30 per cent of the total crop requirement as it is a potential source for readily available nutrients. This contains beneficial microbes and growth promoting substances that help for betterment of crops. Also their application in different field crops at recommended dosages has been reported to reduce the requirement of chemical fertilizers is a alternative approach for enhancing the sustainable production.

Green manure plays a vital role in improving soil fertility by the way of improving soil physical, chemical and biological properties, supplying the nutrient to succeeding crops (Saini *et al.,* 2019) and it reduce the usage of fertilizer. Palled *et al.* (2000) reported that organic matter of soil was increased by green manuring in maize-groundnut cropping system. Incorporation of dhaincha reduced the NPK rate to one third without reducing the rice and wheat yields in rice-wheat cropping system (Naik and Yakadri, 2004). Parallely, Acharya *et al.* (2008) presented that application of 25 per cent of recommended dose of N either through farm yard manure or by *in situ* green manuring with dhaincha (*Sesbania aculeata*) in rice recorded higher net production values in all the rice-based cropping systems. Consequently, organic manures had direct and residual effects on rice and wheat yields, whereas the effect of poultry manure was more beneficial in a wheat-rice cropping system (Bodruzzaman *et al.*, 2010).

These findings suggest that nitrogen, phosphorus and potassium are the major nutrients in crop production and a balanced ratio of all the nutrients are important in plant nutrition perspective. Total N uptake and protein synthesis are reduced in K deficient plants and excess of N in relation to other nutrients, such as P and K can delay crop maturity. Integrated management of chemical fertilizers and organic wastes such as vermicompost and poultry manure may be an important strategy for sustainable production of crops. This may not only improve the efficiency of chemical fertilizers, but also increases crop yield, by improving available forms major and minor nutrients in the soil (Rautaray *et al.,* 2003).

Influence of cropping system on soil available nutrient status

Different cropping systems have varied effects on the available nutrient status in the soil due to their varying

metabolism of nutrient uptake. In typic rhodustalfs, a study conducted by Tarafdar *et al.* (2008) revealed that rice-based cropping sequence with RDF + FYM was more effective for enhancing soil carbon density (43.20) and stock (40.60) and in sequestering CO_2 (30.32 t/ha), while pigeonpea-based cropping sequence was more proficient in raising available N (45.80), P (296) and K (2.20). Blackgram and rice-based cropping sequences depleted available K by 13.00 to 18.60, while pigeonpea-rice sequence in a cycle of four years enhanced the K availability by 9.90. This pigeonpea-rice sequence also increases Zn availability (17.50 to 31.90); reduces Fe and Mn toxicity. Also it maintains the soil pH, while rice-rice sequence enhances Cu availability.

In Himachal Pradesh, available NPK was higher (267.21, 19.99, 172.42 kg/ha, respectively) under vegetable based cropping system as compared to fruit, cereal crop, agroforestry systems. Wherein, carbon density in surface soil ranged from 11.33 to 15.39 Mega gram C/ha and total carbon sequestered upto 30 cm soil depth ranged from 601.96 to 12646.29 Giga gram carbon. Hence, the commonly occurring cropping systems did not influence the soil properties and nutrient availability adversely. Agroforestry based cropping system is having higher potential of sequestering soil carbon. Therefore, to adapt changing climatic situation and to mitigate its effect in this region, agroforestry based cropping system need to be encouraged (Nancy *et al.*, 2016).

Residual effect of nutrient on cropping system

Each crop sequesters the required nutrients and the rest of unused and newly released nutrients are left in the soil as residual, the results obtained by Hankare *et al.* (2005) in wheat - maize cropping system all the growth and yield contributing characters of wheat were not influenced significantly due to fertilizer treatments given to the preceding crop of maize which indicates that there was no residual effect of fertilizers applied in different doses and forms to the preceding maize: Since maize is a heavy feeder crop, residual effect of organic manures had a marked increase in grain yield over no manure application (Reddy *et al.,* 2005). In another study with different manures used, composted poultry manure recorded higher grain, stover and protein yields in maize which were significantly higher over FYM and urban garbage compost. Whereas the poultry manure was on par with sewage sludge and enriched urban garbage compost in groundnut-maize cropping system. The superiority of composted poultry manure attributed to its slow and steady decomposition, to release the nutrients slowly as compared to other organic materials.

Residual effect of organics was also noticed by Reddy and Reddy (2005) wherein plant height, number of leaves, leaf area, yield attributes and root yield in radish as significantly affected due to the residual effect of vermicompost in onion-radish cropping system. While conducting research on maize-greengram cropping system by Bharathi and Poongothai (2008), the sulphur applied to the first crop further increased the grain and stover yields significantly in the residual crop. The yield parameters *viz.,* number of pods per plant, number of grains per pod and 1000 grain weight were favorably influenced by the residual sulphur.

Nutrient uptake by the cropping system

In soybean - wheat cropping system, nutrient uptake (N, P and K) were significantly higher with the application of RDF + FYM which was on par with organic manures *viz*., compost + Green leaf maure (GLM), vermicompost + GLM and compost + vermicompost + GLM in combination with beejamrut + jeevamrut + panchagavya treatments. Lower uptake of N, P, K were recorded in beejamrut + jeevamrut treatment (Shwetha, 2007). Results of the study carried out by Rasool *et al.* (2008) in sandy loam soil on maize - wheat cropping system revealed that the application of FYM to maize increased the OC by 16 per cent whereas NPK of 100:50:50 increased the same by 21 per cent. Higher OC with both FYM and NPK of 100:50:50 increased the total soil porosity and decreased soil bulk density from that in control plots. The grain yield and uptake of N, P and K by both maize and wheat were higher with the application of FYM and inorganic fertilizers than in control plots. The uptake of N, P and K increased with the application of FYM and NPK of 100:50:50.

Among the maize based nutrient management practices, maize + cowpea - groundnut system recorded significantly higher nutrient uptake (125.85, 25.02 and 62.87 kg NPK/ha, respectively) followed by maize + frenchbean - groundnut system (121.02, 23.04 and 61.16 kg NPK/ha, respectively) (Somashekharappa, 2012). Among the different soybean based cropping systems in sandy loam soil, total P uptake by soybean did not differ significantly. Soybean grown under soybean - wheat - mungbean system had significantly higher total uptake of N as well as K over soybean - wheat - fallow system (Prajapat *et al.,* 2015).

Nutrient balance in soil

In intensive crop rotations and multiple cropping systems, it is essential to determine the amount of nutrients removed by various crops from the soil. Such information would indicate the extent to which a crop in the sequence would enrich or exhaust in the soil and would be helpful in making suitable modification on the manure schedule, so that the fertility status of soil will get improved. In reclaimed sodic soils, use of inorganic fertilizers with and without organic manures significantly influenced the available N, P, K and OC content of the soil. Application of 100 per cent N resulted in decline in available N, P and K from the initial values as compared to balanced application of 100 per cent NPK (Yaduvanshi, 2001).

In sandy loam soils of Bajaura, Parmar *et al.* (2002) reported that higher available N and P which recorded a 100 per cent of NPK along with FYM and a higher available K was observed in 100 per cent NPK application than in

control in a long term experiment under maize-wheat cropping system. In long term experiment under soybean - wheat cropping system in vertisol, the integrated application of FYM 15 t/ha along with 100 per cent recommended dose of NPK fertilizer led to a higher value of available N (290 kg/ha), P (39.4 kg/ha) and K (310 kg/ha) (Tiwari *et al.,* 2002). With different cropping sequences, in dhaincha - gobhi sarson cropping system, a maximum of N balance in soil at all levels of N application was observed. This was followed by soybean - gobhi sarson, blackgram - gobhi sarson and maize - gobhi sarson where positive N balance was observed at 40-160 kg N/ha. The balance sheet of N showed that there was gain of N in soybean - gobhi sarson and blackgram - gobhi sarson sequences, whereas it was negative in dhaincha - gobhi sarson and maize - gobhi sarson sequences (Thakur *et al.*, 2003).

Under long term field experiment, in pearl millet - mustard cropping sequence, application of P along with nitrogen increase the available P, further application of potassium had increased available P when compared to 100% N application alone Khambalkar *et al.* (2012). The magnitude of increase in available P under 100 per cent NP and 100 per cent NPK was 11.0 and 13.5 per cent over control (9.61 kg/ha). However, higher available P content (13.12 kg/ha) was recorded in integrated use of 100 per cent NPK along with of poultry manure @ 5 t/ha (Lakshmi *et al.,* 2012). Under long term experiment of ten years in sandy loam of Orissa by Pal *et al.* (2006), a higher available N, P and K contents (165, 12.5 and 245 kg/ha) with application of 30 kg (N) through FYM + 20 kg P + 20 kg K/ha was attained. Stalin *et al.* (2006) observed that the integrated application of coir pith compost along with chemical fertilizers increased the soil available nitrogen content in post-harvest soils of rice from an initial value of 231 to 241 kg/ha. The nutrient status under continuous cropping of soybean and wheat in vertisol was found to increase the OC content from initial value of 5.7 g/kg to 9.6 g/kg by the treatment of 100 per cent NPK + FYM while OC content was decreased in control (4.2 g/kg) followingly 100 per cent N (4.8 g/kg) in plots after 36 years of continuous cropping was observed (Thakur *et al.,* 2011).

Effect of preceding crops on succeeding crop in cropping systems

A report by Kumar and Sharma (2000) revealed that wheat preceded by daincha exhibited higher N uptake at all growth stages than preceded by cereals and oilseed crops. Application of phosphorous to previous wheat crop at variable levels created differential residual P status and significantly increased the yield and dry matter production of succeeding cowpea crop (Vig and Saroa, 2001). The crop wise pooled results over 25 years have indicated significant improvement in crop productivity with integrated use of organic and inorganic fertilizers by 11 to 44 and 15 to 26 per cent, respectively over optimal (100 per cent NPK) and super optimal (150 per cent NPK) levels and the beneficial residual effect varying between 11 to 31 per cent on the succeeding crop in the sequence in different soil groups (Vats *et al.,* 2001). A trial conducted to evaluate the residual effect of organic manure, phosphorous and gypsum application in preceding groundnut for soil fertility and productivity of Indian mustard results revealed a residual effect of 60 kg P_2O_5 which significantly increased the siliqua/plant, seed weight/plant and 1000 seed weight and thereby the total seed yield of Indian mustard, was increased by 9.7 per cent over 20 kg P_2O_5/ha (Rao and Shaktawat, 2002).

A positive balance of soil available N, P and K was recorded for two years in soybean-wheat cropping system. However soybean based cropping systems enriched the soil N especially during the application of recommended doses of nitrogen (Ramesh and Reddy, 2004). Soil available nitrogen was significantly higher in sandy loam soil when intercropped with leguminous crops like, pigeon pea, greengram, cluster bean, field bean, blackgram and groundnut. Intercropping of pulses with finger millet would reduce the use of external inputs due to the complementary use of nutrient and water resources by the intercrop components. Thus legumes grown under low fertility soils could improve the soil health by fixing the atmospheric N and would partially supplement the use of inorganic fertilizers in the field (Triveni *et al.,* 2017).

CONCLUSION

Sustainability in agriculture can be attained by effecting proper management of inputs in a designed cropping system. This review focuses on a pre-requisite plan of choosing the appropriate crops in a cropping system. Analysing the residual nutrients in the soil before sowing could further optimize the incubation of input management which ultimately preserves the soil health. Hence, analysing the field, optimizing the use of fertilizers and incorporation of green organic manures leads to a higher gross benefit for the farmers.

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