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Towards Sustainable Intensification of Maize (*Zea mays* L.) + Legume Intercropping Systems; Experiences; Challenges and Opportunities in India; A Critical Review

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World population is projected to reach over 9 billion in 2050. At present ensuring food security while mitigating environmental impacts represents a major agricultural challenge. Thus, higher productivity must be reached through sustainable management by taking climate change into account, resources rarefaction like nutrient light and water and fatalities of fertile lands. Crop diversification is now recognized as a decisive part for sustainable agro-ecological development. Growing legumes in western Uttar Pradesh not only major biological nitrogen source but also a powerful option to reduce synthetic nitrogen fertilizers and associated consumption fossil energy. Inclusion of legumes in the cropping system has been known since times immemorial. Legume help in solubilizing insoluble P, improving the physical condition of soil, increasing soil microbial biomass and restoring organic carbon and also has smothering effect on suppressing weed. The carryover of N released from legume for succeeding crops in intercropping system is also imperative. In a country like India, where the average consumption of nutrients by chemical fertilizers is low, the scope for exploiting direct and residual fertility due to maize+legumes intercropping has a great potential. This review deals with the important aspect of legumes on increasing productivity and nutrient use-efficiency in various intercropping systems. Maize and mashbean/greengram is stronghold in marginal and sub-marginal lands. Maize yield increased when sown with legume. Grain legumes like mashbean, mungbean and redgram provide an equivalent to 70 kg N ha^{-1} on main crop. Various studies have shown that among legume/cereal intercropping system, the combination of maize/mashbean is considered to be highly suitable with a minimum competition for nutrients, water, light and space besides resource use-efficiency. Nitrogen economy in maize+legume is still a researchable issue because the key point for leguminous crop grown with maize in intercropping system is nodulation problem. Legumes with indeterminate growth are more efficient in N_2 fixation than determinate types. Intercropping enhanced higher and more stable grain yield than the mean sole crops, higher cereal protein concentration than in sole crop (11.1 versus 9.8 %), higher and more stable gross margin than the mean sole crops and improved use of abiotic resources according to species complementarities for light interception and use of both soil mineral nitrogen and atmospheric N_2.

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Food security is a major concern in the Asian region. Wherein urban food price is extremely high, which aggravating food insecurity among subsistence urban households. Although, among the food crops, maize is the main staple (Dwivedi *et al*., 2015c), and legumes are an important food for the rural poor (Onwueme and Sinha, 1991). In India, the demand for maize is projected to increase by at least 26% over the next ten years; and the demand for legumes by 62% (FAOSTAT, 2010). Intercropping is an ancient practice, placed on the fringes of a 'modern agriculture' dominated by large areas of monocultured, resource-consuming and high-yielding crops (Vandermeer, 2010; Zhang *et al*., 2010; Li *et al*., 2014). However, intercropping may be a means to address some of the major problems associated with modern farming, including moderate yield, pest and pathogen accumulation, soil degradation and environmental deterioration (Vandermeer, 1989), thereby helping to deliver sustainable and productive agriculture (Lithourgidis et al., 2011). In countries like India, where the amount of cultivated land per capita is decreasing steadily, inherently indigenous technical knowledge (ITK) and sustainable local practices adopted before the Green Revolution have been systematically replaced. For instance, the subsistence agriculture of the pre-chemical era efficiently sustained the status of nitrogen in soils by maintaining a balance between N gained from biological N fixation and N lost with the grain harvest. This was possible with less intensive cropping system, adoption of crop rotations and intercropping systems, and the use of legumes in crop rotation with cereal. However, the agriculture of the modern chemical era concentrates on maximum output but overlooks input efficiency. There is now increasing evidence that chemical fertilizers alone cannot sustain yields for long periods of time because crops utilize hardly 30 to 40% of the applied fertilizer nutrient and the rest is lost through various ways like leaching, volatilization, surface runoff, denitrification, soil erosion and fixation in soil. Consequently, best efforts have to be made to develop site-specific plant nutrient technologies to improve the use efficiency of the nutrients from which the demand can be minimized for this costly input. However, seasonal variability causes wide losses in food crop yields, including maize and mashbean. Summer maize–legume cropping systems show considerable promise in boosting productivity and helping reverse the decline in soil fertility that is a fundamental cause of low smallholder productivity in India (Dwivedi *et al*., 2015c). Moreover, Maize and mashbean co-exist in all maize agro ecologies of India (Dwivedi *et al*., 2015a). Nutrient stress (toxicities and deficiencies) are becoming increasingly widespread in many soils of the world due to not using of organic manures and indiscriminate application of high-analysis fertilizers, responsible for low crop productivity. For example, in continuous rice cropping with two to three crops grown annually, the use of fertilizer nitrogen increased with duration but the yields often remained stagnant. Continuous rice-rice cropping under wetland conditions leads to a low level of available soil nitrogen, until it is replenished by fixation of biological N.

Most maize-growing areas in the country can be regarded as maize–legume based farming systems; the difference lies in the maize varieties and legume species grown. Grain legumes are planted as intercrops, alleys and rotations with maize in mid-altitude sub-humid (common beans and soybean), highlands (fababean and chickpea), dry land (common bean, pigeon pea, cowpea and groundnut) and low altitude sub-humid (cowpea) ecologies. Response of maize+mashbean intercropping system to planting geometry and nutrient management in western Uttar Pradesh was carried out in India. Intercropping systems involve two or more crops growing together and co-existing for a time. This latter criterion distinguishes intercropping from mixed mono cropping and rotation cropping (Vandermeer, 1989; Li et al., 2014). Intercropping is common, particularly in countries with high amounts of subsistence agriculture and low amounts of agricultural mechanization. Intercropping is often undertaken by farmers practicing low-input (high labour), low-yield farming on small parcels of land (Ngwira et al., 2012). Under these conditions, intercropping can support increased aggregate yields per unit input, insure against crop failure and market fluctuations, meet food preference and/or cultural demands, protect and improve soil quality, and increase rural income (Rusinamhodzi et al., 2012). Not all intercropping systems provide benefits. For example, in temperate regions, grain legumes with cereals intercropped as forage yield variable gains depending on the cereal and legume, the specific growing conditions and the sowing ratio (Anil et al., 1998); legume+cereal mixtures often give lower protein and biomass yields than sole cropped cereals. When intercropping benefits do occur, they emerge from more complete exploitation of resources, such as water, solar radiation, soil and fertilizers, from beneficial neighbor interactions (facilitation), and in some cases from continuous soil cover (Vandermeer, 1989). But there are constraints: intercropping may be undesirable when a single standardized product is required, and might have lack economies of scale for labour and time management. Intercropping has not usually been seen as suitable for mechanization in an intensive farming system (Feike et al., 2012). Despite its potential benefits, intercropping faces huge competition from large-scale, intensive monocrop farming. Thus, to ensure their uptake and enable sustainable agricultural intensification, intercropping systems must be optimized to enhance crop yield and resource-use efficiency simultaneously (Li et al., 2014), while it also promoting wider benefits, including the delivery of multiple ecosystem services and goods. A primary challenge for researchers is in understanding the processes and mechanisms underpinning intercropping and the goods it delivers. Such knowledge could allow manipulation of intercropped systems to maximize desired outcomes (e.g. food production, landscape quality or biodiversity conservation) and thus promote its wider uptake. Although, it is in this context that legumes again assume great importance to sustain soil fertility in cropping systems operating at high productivity levels. Due to this, Legumes are known to fix atmospheric N, legume crops are a natural mini-nitrogen manufacturing factory in the field which can play a potential role in increasing indigenous nitrogen production in the field. Some legumes namely mungbean and mashbean have the unique ability to solublize occluded P and highly insoluble calcium-bound P by their exudates of root in addition to improving the soil fertility. Legumes help in improving the soil physical condition, improve soil microbial activity and also restoration of organic matter, besides help in disease and pest control.

The overall objective of this study is to increase food security, sustainability, performance and productively and incomes at household and regional levels, besides contribute to the economic development of the country through maize-based cropping systems. The experiment which has SVPUAT Meerut as the executing institution is funded by them. It is designed to fit the regional agricultural development priorities of western Uttar Pradesh. It aims at increasing farm-level food security and productivity, in the context of climate risk and change. It also promotes conservation agriculture (CA) based maize+mashbean integration to result in resilient, profitable and sustainable cropping systems that overcome food insecurity for significant numbers of farm families of the country *vis-a-vis* improving crop productivity and nutrient use-efficiency. This paper presents the key achievements of the experiment in India since its inception.

Major activities undertaken

Identification of target research area

The current activities were undertaken in two maize+mashbean based cropping systems classified broadly as a latitude of $29^0$40' North and longitude of $77^0$42' East with an elevation of 237 metres above mean sea level. The area lies in the heart of Western Uttar Pradesh.

In these zone, moisture stress (drought) is the main limiting factor for crops and livestock production because rainfall is erratic and insufficient, a situation aggravated by high evapo-transpiration rates. Irrigation and water harvesting techniques and technologies for the efficient use of the limited rainfall are although, well developed. The activities in the drought-prone areas of the alluvial valley region of India were conducted at Crop Research Center Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, has a semi-arid and sub-tropical climate characterized by hot summers and severe cold winters. The mean maximum temperature was noticed in June, which is the hottest month of the year, ranging from 40 to 45^{o}C. The mean annual rainfall is about 650 mm, of which nearly 80 per cent is received in the monsoon period from July to September and the remaining in the period between Octobers to May. The mean daily pan evaporation value reaches as high as 16.0 mm in the month of June and as low as 2.2 mm in the month of January. The mean annual pan evaporation reaches about

850 mm. The mean wind velocity varies from 3.5 km/hr in October to 6.4 km/hr during April. Mean relative humidity attains the maximum value (70 to 77% or even more) during the monsoon season and the minimum (30 to 45%) during the summer season. The weather data for the experimental period was recorded at the meteorological observatory of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut. In general, the mean monthly temperature decreased from June to October. The mean weekly maximum temperature was 39.2^{0}C which was recorded in the last week of June. It decline gradually and reached to its minimum at the time of harvest. Minimum temperature follows the same trend as of maximum temperature, though the lowest temperature was 18.1^{0}C during the third week of October. The mean weekly relative humidity at 7.00 and 14.00 hrs varied from 80.8 to 59.9 and 73.7 to 23 per cent, respectively. The total rainfall received during crop period was 651.6 mm.

On-station evaluation of best-bet options under representative agro ecologies

Prior to preparing the trials, soil properties of the trial sites in each research center were characterized. The experimental field was well drained, sandy loam in texture (46.2 % sand, 18.4 % silt and 17.4 % clay) and slightly alkaline in reaction (pH 7.8), It was medium in organic carbon (0.570 %), available nitrogen (222.6 kg/ha) and available phosphorus (16.6 kg/ha) but high in available potassium (249.0 kg/ha) with an electrical conductivity (1:2, soil: water suspension) and Bulk density of 1.6 dS/m and 1.42 Mg/m3, respectively. The treatments comprised of 2 cropping systems (maize+mashbean and maize alone), 2 planting geometries (normal and paired planting) and 3 fertility levels (control, 100% NPK and 100% NPK + Zn + PSB), replicated thrice in a factorial randomized block design. Varieties PAC 712 (Maize) and PU 19 (Mashbean) with the spacing (rows) of 50 cm (Normal) and 30/70 cm (Paired) were grown with recommended agronomic package of practices. The seeds were placed manually in the furrows at a plant to plant distance of 20 and 10 cm with a seed rate of 20 and 15 kg/ha for maize and mashbean, respectively and sown on 30 July 2012. The 100 per cent NPK (for maize) is characterized by 120 kg N, 60 kg P_2O_5 and 40 kg K_2O/ ha and Zn is applied @ 0.5% $ZnSO_4$ as spray whereas, PSB is used as seed treatment @ 20 g/kg of seed. Irrigation was provided as per need of crop. Crop were kept weed free by regular hand weeding. The data on growth, yield, total nutrient uptake, soil nutrients status and economic analysis was recorded as per the standard procedure. The data obtained were subjected to statistical analysis as outlined by Gomez and Gomez (1984). The treatment differences were tested by using "F" test and critical differences (at 5 per cent probability).

Effect of intercropping on growth and yield of maize

Maize has been recognized as a common component in most intercropping system in the tropics (Ijoyah, 2012). Prasad and brooks (2005) found an increase in maize plant density to significantly affect the LAI in maize soybean intercropping. While Fawusi and wanki (1982) reported a high leaf area index and light interception for maize in mixture over sole crops. Thus, increase in the growth of maize was also reported by Adesoji et al. (2013) to be as result nitrogen effects that lead to increase cell expansion, cell division and increase in size of all its morphological parts. Even Reddy and Reddy (2007) observed separately the grain yield of maize to have increased after intercropping with groundnut and black gram. Similarly, Maluleke et al. (2005) found maize dry matter was reduced with increasing Lablab population. Mangasini et al. (2012) found the vegetative growth of component crop in a mixture is affected by intercropping. Thayamini and Brintha (2010) noted that the planting pattern of the maize and legume did not affect the yield of maize. The purpose of maximum maize + legume association is to reach a full yield of the maize plus selected legume yield (Chui and Richards, 1984), however reported decline in yield of maize as a result of varying spacing in intercrop system with cowpea. This further agrees with the report of Gangwar and Sharma, (1994) revealed that there was decreased yield of maize due to intercropping of legumes namely cowpea, clusterbean, sunhemp and dhiancha. Also experiment conducted at the Indian Agriculture Research Institute found a significant dry matter accumulation of maize and groundnut intercropped in the 1:1 row ratio arrangement (Kumar, 2004). Ali and Mohammad (2012) observed that the highest dry leaf/dry stem yield and total protein of plant was related to forage corn intercropping with Karaj and Multicut respectively. Chui and Richards (1984) reports that intercropping hindered maize tasseling and silking by up to 2 days, particularly at the full population concentration of soybeans. Intercropping maize with cowpea was seen to significantly decrease cob length, ear length, dry cob weight, dry grain yield and total dry plant biomass (Egbe et al., 2010). Plant density affects both intra and inters specific competition and has particularly a strong effect on grain yield of maize (Flores-sanchez et al., 2013). Maize+legume intercrop could substantially increase the quality and quantity of forage (Ali and Mohammad, 2012). Farmers' field was however noticed to have had the highest amount of vegetative biomass when legume crops are intercropped with maize (Amos *et al*., 2012).

Effect of intercropping on growth and yield of legumes

Research work revealed that space for higher cereals can be altered to a certain degree without reducing its yield while providing a more promising environment for the intercropped legume (Chui & Richards, 1984). Likewise, Bhagad *et al*. (2006) mentioned that Intercropping arrangement did not influence 100 kernel mass, however weight of pods apiece hill, number of pods per hill and shelling per cent were significantly subjective due to different treatments. Hongchun et al. (2013) reported that intercropping with maize did not disturb fresh weight associated with mono cropping. The use of twin rather than single irregular rows of each species improved intercrop soybean yield without materially varying maize performance comparative to mono cropping (Maluleke et al., 2005). Intercropping significantly condensed the number of soybeans leaves per plant by 58%, leaf area index (LAI) by 75% and phytomass at start seed - filling by 78% (Maluleke et al., 2005), however, Chui and Richards (1984) maintained that grouping maize plants at three to a hill enlarged intercrop soybean leaves per plant, LAI and phytomass relative to the conservative maize planting of one plant per hill.

Effect of intercropping on nutrients uptake

Phosphorus achievement by soybean was significantly amplified by P application in intercropping (Li et al., 2001). Legumes as a catch crop can reduce K and nitrate leaching (Askegaard and Eriksen, 2008) and act not only as a N_2 fixing crop but also use as a catch crop by taking up additional soil minerals N, P and K. These findings make legumes an important tool in the cropping systems where N and K are the major yield limiting factors (Flores-Sanchez et al., 2011). Rusinamhodzi et al. (2012) reports that deficiencies of micro nutrients such as Zinc, boron and molybdenum in the field may bound legume growth as well as limit nitrogen fixation. Similarly, legume and maize raise together, phytosiderphore released from maize roots may mobilize Fe^{+++} and profit the iron nutrition of plant (Fusuo and Li, 2003). Peanut/maize intercropping is known to progress Fe nutrition in all peanut tissues (Hongchun et al., 2013). Li et al. (2001) reported that nitrogen acceptance by maize in an intercrop is greater as relate to sole cropping. The greater N acquisition by a non - legume crop intercropped with a legume is often reported in literature (Francis, 1986; Vandermeer, 1989; Stern, 1993). This may probably be due to the effect of competition. However, nitrogen attainment by soybeans was not significantly affected by intercropping. Even when Geiler (2001) reported soil pH to have extensively influence nodulation and can make deficiency of some essential nutrients such as P and Mo, it was further reported that intercropping greatly augments Fe and Zn concentration in seeds of peanut (Hongchun et al., 2013).

Intercrop productivity

Intercrop productivity, otherwise called yield advantage is core in any intercrop studies. Production systems involving inter planted food crops are widespread in tropical latitudes (Thayamini & Brintha, 2010). Intercrops are greatest productive when the component crop varies greatly in growth duration so that their maximum condition for growth resources occurs at different periods (Ijoyah, 2012). The several factors interaction will optimize the most effective use of restrictive resources in intercrop (Fukai and Trenbath, 1993). These factors are to be range from the genetic constitution of the component crops to environmental and agronomic manipulation of the micro environment (Fukai and Trenbath, 1993). Early maturing constituent is grown with little interference from the late growing crop resulted high intercrop productivity. Thus, the choice of agronomic manipulations and accurate cultivars to certify the most effective use of limiting resources is key part for high crop yield (Thayamini and Brintha, 2010). The highest yield advantage and complementary effect come about when component crops have different growing periods to make their demand on resources at different times (Ijoyah, 2012). Fukai (1993) maintained that legumes are a shared component of an intercrop, and their skill to fix nitrogen often supports the productivity of the intercrop, or subsequent crops.

Moreover, Rao and Willey (1980) showed a clear variation in duration of maturity of component crop was due to largely the advantage in yield, which clearly allowed in this combination for a good resource use with time. Khan et al. (1992) in an experiment involving maize and soybean recorded a high LER of 1.40 as a result of sowing them in same rows, while a low LER of 0.95 involving the same crops was noted but on alternate rows. Although, LER values in 1:2 row ratio at 100 per cent + zero per cent fertilizer (maize 60/90 cm-rice bean 30 cm), in 2:3 at 100 per cent fertilizer (maize 150/15-rice bean 30 cm) and in 2:5 at 100 per cent + 100 per cent fertilizer were 1.84, 1.87 and 1.97 respectively.

Effect of legumes intercrop and cropping system on soil fertility

Soil fertility problems are not only an agronomic issue, but also strongly related to economic and social issues. Intercropping tend to ameliorate some of the fertility constraint of poor farmlands.

Adeleke and Haruna (2012) mentioned that pulses are usually intercropped with cereals and advance land productivity over soil amelioration. In a study, Vesterager et al. (2008) found maize and cowpea intercropping as beneficial on nitrogen poor soil. Maize /cowpea intercropping increases the amount of nitrogen, phosphorus, and potassium contents associated to monocrop of maize (Dahmardeh et al., 2010). Degraded and infertile soils are realized as a result of continuous monocropping and insufficient organic matter reprocessing coupled with occurrence of rainfall variability marked by common dry spells account for low crop yield (Amos et al., 2012). It was further noted that the understanding of the fact that maintenance and improvement of soil fertility cannot be exclusively through the use of predictable fertilizers (Amos et al., 2012). As a trait in legumes as cover crops, conservation involves minimum soil disturbance, permanent sol cover with living or dead plant resources, and diversified crop rotation and associated by legumes crops (Amos et al., 2012). Adeleke and Haruna (2012) also in the result of their findings revealed increase in total nitrogen after cropping any of the four legumes (soybean, cowpea, lablab and groundnut) and when the land was left fallow. This monumental increase in the total nitrogen was probably due to the ability of the legumes to fix atmospheric nitrogen in the soil through symbiotic N fixation. This symbiosis alone accounts for more than 20% of global biological nitrogen fixation and has been calculated to contribute 45-50 million tons of fixed N to agriculture each year (Geiler, 2001). Also the higher Cat ion Exchange Capacity (CEC) which plots that were previously cropped to legumes and had compared with the previous maize plot and fallow plots could be attributed to the leaf litter droppings which more or less serve as mulch and later decomposed to add nutrients to the soil (Adeleke and Haruna, 2012).

Resource use

Intercropping systems can allow for spatial and temporal increase in nutrients uptake (Flores-sanchez et al., 2013). Spatial nutrients uptake can be increased through the increasing root mass (Undie et al., 2012), while temporal advantage in nutrients uptake occur when crops in an intercropping system have their peak nutrients demands at different times (Anders et al., 1996). Similarly, plants species with differing root and uptake patterns, like the case of legumes/cereals in intercrop, more efficient use of available nutrients may occur (Matusso et al., 2012), and higher uptake of nitrogen in the intercrop have been reported (Seran and Brintha, 2010; Undie et al., 2012; Flores-sanchez et al., 2013) whereas in intercrop their similar root orientation tends to compete together at the same surface level (Hamidou et al., 2013). Intercropping amid high and low canopy crops is a mutual practice in tropical agriculture. Total system light Interception is resolute by crop geometry and foliage architecture (Trenbath, 1986). In intercropping between high and low cover crops is to improve light interception and hence yields of the smaller crops requires that they be planted among sufficiently wider rows of the taller ones (Seran and Brintha, 2010). A favorable microclimate is created by intercropping for the lower plants growth. Keating and Carberry (1993) have reported a better use of solar radiation by intercropping soybeans and Maize. Further to that, intercropping enhanced the efficient use of strong light by maize and weak light by groundnuts which subsequently lead to yield advantage (Jiao et al., 2008). A combined leaf canopy might make better special use of light (Waddington and Edward, 1989). Growth of plants in any cropping system is vital and is determined by the availability of water and it efficient use lead to increase use of other resources (Dahmardeh et al., 2010). Water capture by intercrops is 7% higher than as compared to mono crop (Morris and Garrity, 1993). Chui and Richards (1984) further maintained that during competition light obviously increase internode elongation on soybeans. Further to that, a delay in sowing of four weeks was long enough to avoid interspecific competition for light and nutrients and allow a good establishment of both maize and roselle (Flores-sanchez et al., 2013). Despite the beneficial effects of the intercropping to the cereal crops, it may also quicken soil nutrient depletion, particularly for phosphorous, due to added efficient use of soil nutrients and higher exclusion through the harvested crops (Mucheru-Muna et al., 2010). However, Chalka and Nepalia (2006) found that maize intercropped with soybean produced significantly lower NPK depletion and higher N uptake. And, recent efforts on replenishment of soil fertility in Africa have been through the introduction of legumes as intercrop and/or in rotation to minimize external inputs (Sanginga and Woomer, 2009).

Above and Below Ground Interaction in Intercrop

Light is a vital factor that determines yield (Jeyakumaran and Seran, 2007) especially when two morphologically dissimilar crops with different periods of maturity are intercropped (Ijoyah, 2012). Most of the advantages gotten from growing crops in intercrops come largely from the ways in which the crop mixtures balance each other in their exploitation of the environment (Oyewole, 2010). Indeed corn canopy architecture plays a significant role in the amount of sunlight radiation intercepted by other crops sown in an intercropping pattern (Metwally et al., 2012). The reduction of light intensity caused by the corn plant reduces the photosynthetic capacity of a second crop in an intercrop pattern (Metwally et al., 2012). Crop biomass buildup depends on light interception by leaves and on the effectiveness, with which the intercepted light is used to produce dry matter (Oyewole, 2010). Yield is determined principally by crop biomass, which in turn is determined by the quantity of radiation intercepted by the crop canopy (Oyewole, 2010). Any influence on the plant canopy either as a result of plant shading, which may result from intercropping, or other resources will affect yield. Crops - weeds competition is well - known by growth habit of crops (Dimitrios et al., 2010). Increased leaf cover in intercropping system helps to reduce weeds population once the crops are established (Beets, 1990). Flores-Sanchez et al. (2013) reported the contribution of above ground and below ground interaction of maize/wheat to be 50 and 59% respectively due to increase in nitrogen uptake. In a report by Hongchun et al. (2013), that through inter-specific root connections, peanut/maize intercropping contribute to the peanut nourishment of some nutrients elements including improvement in shoot zinc (Zn), Phosphorus (P), and Potassium (K) concentration. The nitrogen (N) productivity in both peanut and maize are improved. Mixed grown cereal and legumes have many advantages in terms of growth and some other agronomical properties (Singh et al., 1986; Putnam et al., 1986). There are also significant handicaps of mixed grown component crops such as root competition for water and nutrients and competition for light (Ofori and Stern, 1987; Portes, 1984). Innis (1997) explained that water loss in the soil is reduced by various root systems, these increases transpiration and tend to produce a microclimate cooler than the surrounding. Flores-sanchez et al. (2013) further reported that the aboveground biomass of maize was not affected by legume intercrop neither in the maize monoculture nor in the maize-roselle mixture. It is clear that intercropping patterns caused a significant reduction in light interception through adjacent corn plants and produced taller component crop (Metwally et al., 2012). Legume residues generally create a mulching layer that increases the physical barrier for early germination; such effects do require sufficient residual organic material on the soil surface (Flores-Sanchez et al., 2013). In the soil, facilitative root interaction are most likely to be of great importance in nutrient-poor soil and low input agro ecosystem due to the crisis in inter specific competition or facilitation for plants growth factors (Dahmardeh, 2013). Maize benefit from intercropping with peanut due to extensive root system of maize for absorption of water and nutrients , and possibly that peanut via N fixation could secret H+ in soil (Flores-Sanchez et al., 2013); this acidification of the rhizosphere could improve the dissolution of phosphorus in the high pH soil (Dahmardeh, 2013). Previous works reported that multiplicative processes in groundnut are sensitive to temperature. Increasing air and soil temperatures condensed fruit-set, number of pods and yield in groundnut (Hamidou et al., 2013). In addition, Oyewole (2010) showed that pod yield of groundnut genotypes declined by more than 50% when flowering and pod formation happened when maximum temperatures averaged 40 °C. Nitrogen and phosphorus connections at the root zone of Bambara groundnut in the soil was reported to be the most probable reason for increases experiential in its growth and yield characters (Nweke & Emeh, 2013).

Use as green manure

Rice based cropping systems are highly exhaustive for soil nutrients; therefore considerable replenishment of nutrients on regular basis is imperative for yield maximization and its sustainability. Nutrient recycling by legume in a cropping system could be component of integrated plant nutrient management. Green manuring is beneficial not only for enhancing the yield of rice and subsequent crops but also for improving the fertility of the soil. Incorporation and decomposition of green manure has a solubilizing effect of N, P and K and some micronutrients in the soil (Zn, Mn, Fe and Cu) and the deficiency of different nutrient elements can be mitigated by recycling of nutrients through green manuring crop. Furthermore, it also reduces the leaching and gaseous losses of nitrogenous fertilizer, thus increasing the efficiency of applied plant nutrients. Meelu and Rekhi (1981) have also shown that green manuring alone can give more yield in rice than obtained with 60 kg N ha^{-1} and burying the green manure one day before transplanting of rice enables the crop to be harvested 15-20 days sooner and hence facilitates timely sowing of the following wheat crop. A 6 to 8 weeks old green manure crop of dhaincha or sunnhemp accumulates about 3-4 t ha^{-1} dry matter and 100 to120 kg N ha^{-1} and supplements up to 50% of the total N requirement of rice by green manuring crop when these are incorporated *in situ*, besides leaving a significant residual effect on the succeeding crop. Green manuring of *Sesbania rostratra* + 30 kg N ha^{-1} gave maize yield *at par* with 90 kg N ha^{-1} alone revealing 60 kg N saving through green manuring (Tiwari et al., 2004). When sun hemp or dhaincha turned under at the time of flowering or before pod filling, the decomposition starts immediately in the soil. Moreover, complete recycling is summer green manuring. This practice had declined as farmers felt they could substitute fertilizer instead grow a crop of economic value. Before the beginning of chemical fertilizers, green manuring with legumes like *Crotolaria* or *Sesbania* was a common practice in the rice-growing zone of the Indian sub-continent. However, the prevailing high cost of fertilizer and growing awareness about decline in soil quality in local region has again aroused interest for green manuring by which Farmers use green manuring primarily to reduce their expenses of chemical fertilizer by reducing 25 % N. The green leaves, flowers, immature pods, and vegetative buds decompose very rapidly as they contain simple sugars, starches, hemicelluloses, amino acids, amides, and aldehydes which are hydrolyzed readily by heterotrophic bacteria (Tandon, 1992). Ammonification starts within two days. These are called "Rapid-N" liberators. The aged shoots, roots, and other woody parts are resistant to decomposition as they contain complex lignin compounds. Biological processes are very slow on these parts and termed as "Slow-N" liberators. The initial fraction (Rapid-N) supplies N at the time of crop establishment and early tillering. The second and third fractions (Slow-N), which are 20-50% of total N, contribute to nutrition at the reproductive phase of crop. About 40% of carbon and 80% of total N present in Sesbania were released in about two weeks. Ammonium-N (15-30 ppm) increases after 5-10 days in the flooded soil. The released N meets the demands of early growth of rice. If it is not synchronized with crop growth needs it is likely to leach and get lost from the system.

It was beneficial to apply phosphorus fertilizer to the green manure crop for more dry matter production, root development and N accumulation, leading to greater saving of N fertilizer in rice (Sharma and Mitra, 1988). Loss of ammonia through volatilization was generally lower when N was applied as ammonia sulphate or urea in combination with Sesbania green manure on 1:1 basis than that with urea or ammonia sulphate alone. Mohanty et al. (1998) observed relatively higher NUE of rice with urea as compared with combined use of GM and urea up to 80 kg N ha^{-1}. However, the trend was reverse at 120 kg N ha^{-1}. The enhanced CO_2 production in the green manure crop amended soils and buffers the soil against pH changes. Green manuring helped in fertilizer N recovery by first crop to the tune of 3.5 % and retention of 2.4 % more N in soil and reduced unaccounted-for N by 6.1%.

Legume effect in western uttar pradesh conditions

By increasing in population pressure more and more marginal and sub-marginal lands are being brought under maize cultivation in dry land areas. It was found that maize yield was increased when sown after cowpea, green gram, and blackgram as the preceding crops. Maize responded to the application of 120 kg N ha^{-1} only, while in case of cowpea grain as the preceding crop, the N dose for maize was 90 kg N ha^{-1}. This could be explained by higher NO_3-N build up in fallow and mungbean/urdbean plots, preceding system. Moreover, Most of the dry lands regions are deficient in nitrogen and organic carbon. In such areas, high costs of N fertilizers reduce its application, inclsion of legumes is necessary for their possible effect in increasing productivity of crops.

Pearl millet alone contributes a mainstay (97%) in dry lands and sub-marginal and marginal lands. System-oriented research in pearl millet has mainly been concentrating on intercropping with green gram, black gram, cowpea and dhaincha. It is generally rotated with *Rabi* crops of wheat, barley, gram and sanflower. Giri and De (1980) reported benefits from grain legumes like groundnut or cow-pea grown for the full season to be equivalent to 60 kg N ha^{-1} on the subsequent crop of pearl millet. in areas receiving more than 600 mm of well-distributed rainfall and having limited irrigation facilities.

Legumes Intercropped With Cereal under Low Moisture Condition

Although, Farmers generally take own decisions on the technologies to be adopted on the basis of cost, risk and returns. In small farms, the farmers raise crops as a risk minimizing measures against total crop failures and to get different produces to take of his family food, income, etc. Moreover, Benefits of intercropping may be briefed as: improvement of soil fertility by legume components of the system, better use of resources, soil preservation through covering the bare land between the rows, reduction of abiotic and biotic risks by increasing diversity, suppression of weeds infestation, etc. In intercropping system involving legume and non-legume, legume may provide nitrogen benefiting non-legume component, which improve nitrogen uptake and fertility status (Dwivedi *et al*., 2015a). However, As a result of concerted research efforts, stable and remunerative intercropping systems have been identified for different agro-climatic regions of the country. These are some of the examples where it was possible to harvest almost full yield potential of the cereal component. In intercropping system, legume is grown for grain/fodder/green manure, besides increasing the total productivity of the system and also plays a key role in economizing the use of resource, especially N. It has been estimated that by inclusion of legumes in intercropping system, the extent of N addition would be 0.746 million tonnes (Saraf, Shinde, and Hegde, 1990). From a biological point of view, the combination of maize/pigeon pea is considered to be most suitable with a least competition for nutrients. Pigeon pea starts flowering after the maize has been harvested and its period of greatest nutrient demand occurs when the maize has already completed its growth cycle. The major consideration is to quantify the "direct transfer" of N from legume component to the non-legume component grown all together. However, their crop components have different requirement for nutrients. Cereals have required less P but high N, while legumes possess effective mechanism for symbiotic fixation of N but have a high requirement of P. N economy through intercropped legumes is yet to be correctly assessed in different cereal-legume intercropping systems. However, the beneficial effect of intercropped legumes in increasing NUE has been reported in many intercropping systems and

When maize is intercropped with leguminous cover crops, the leguminous crops contribute significantly to N nutrition of the maize crop. Intercropped maize responded to fertilizer only up to 60 kg N ha^{-1} while sole maize responded up to 120 kg N ha^{-1}. It was observed that in maize/ mung-intercropping system the highest utilization of P occurred when P was banded near each mung row (Sinha, Aampiah, and Rai, 1994). Though, the combination of maize+mungbean improved organic carbon, organic matter and available nitrogen, phosphorus and potassium than initial and also highest itself as compared to strip planted maize+urdbean (Pandey *et al*., 2015). In N-uptake study of intercropped maize and cowpea, it was observed that at low N level, the N content of intercropped maize was higher than that of sole maize (Francis, 1986). The benefits of N under sorghum/blackgram intercropping system were observed; it reduced the nitrogen needs of sorghum by 9.0 kg N ha^{-1} (Dusad and Morey, 1979). Whereas, grand growth period of both the crops falls exactly at the same time as a result of which tall cereal adversely affects the growth and development of the associated pigeon pea in sorghum/pigeon pea system. Furthermore, higher amounts of N applied to sorghum/pigeon pea system for better result in growth and yield. Therefore, moderate quantity of N (25-50 kg N ha^{-1}) should be applied to sorghum/pigeon pea system under dry land condition to achieve higher yield advantage. Moreover, Waghmare and Singh (1984) found that the response of sorghum to applied N in different systems was quadratic in sole sorghum and sorghum/ grain cowpea systems but it was linear in other systems. It is interesting to note that the base yield of sorghum in sorghum/fodder cowpea was much higher than that of the highest yield of sorghum in any other systems. This is ascribed to increased growth and uptake of N, P, and K by sorghum as well as effective weed smothering by the intercrops. Moreover, legumes namely soybean, cowpea, pigeon pea, and groundnut grown as intercrop in maize had beneficial residual effect on the yield of following wheat crop (Nair et al, 1979). The N requirement of wheat for the target yield of 4.0 t ha^{-1} was 10.8 kg ha^{-1} after sole sorghum, which was reduced by 87, 61, 83, and 38 kg ha^{-1} after intercropping of sorghum with fodder and grain cowpea, groundnut and green gram, respectively. Furthermore, Wheat yield and N uptake increased when sorghum/legume systems proceeded. Intercropping of sorghum with groundnut; cowpea and greengram reduced the nitrogen fertilizer requirement of following wheat by 30-84 kg ha^{-1} over sole sorghum. Maximum advantage accrued from fodder cowpea followed by groundnut and grain cowpea. In India, 80-90% of pigeon pea is intercropped with short duration crop is the most popular combination in all the pigeon pea-growing areas. Among them, pigeon pea/groundnut system is the most prevalent in dry land since groundnut uses the resources more efficiently and makes rapid canopy coverage to the ground. Studies in the semi arid tropics of India observed that the addition of pigeon pea, as a sole crop or as an intercrop in a cropping system, not only helps build soil N fertility, but also makes more phosphorus reserves available for subsequent crops in the same field (Ae, Arihara, and Okada, 1991a; Ae, Arihara, and Okada, 1991b). However, taking the nitrogen requirement after sorghum fodder as normal, pigeon pea crop contributed only 13 kg N ha^{-1} to succeeding wheat. However, black gram and groundnut as intercrops in pigeon pea proved highly effective in improving the fertility of soil. Likewise, the agronomic significance of nitrogen exertion by legumes crops lies in relatively non-fertile systems where N is limiting factor, and its exploitation may benefit to farmer for subsistence. The key point for the leguminous crop grown in intercropping systems is the nodulation problem. In high input systems, where enough N is available to a crop mixture for maximizing productivity it is likely to that symbiotic N_2 fixation is inhibited and any excretion of N is insignificant. The harmful impact of N fertilizer in row of intercropping may be eliminated by application of N fertilizer to the cereal crop only, although application of slow-release N fertilizers, application of N fertilizer in 10-20 days earlier than the beginning of symbiotic N fixation by legumes, and introduction of *Rhizobium.* Even though, careful localized application of N to the non-fixing component because of nutrients mobility, it is likely to be "seen" in the legume component. Such problems do not arise with phosphorus management under intercropping system. The CEC of roots of legume crop is approximately double to those of cereals. Relatively high CEC of legumes indicates that on soils with low levels of exchangeable K, the legumes would be deficient in K because the roots would adsorb larger amount of divalent cations like K. Because of this, maize have to be more competitive for K than cowpea in intercropping system particularly when N was remain higher. Therefore, K fertilization, which is not a usual practice in intercropping system, required special attention. Moreover, the magnitude of crop-weed competition is generally dependent on component crops in intercropping. Venkateswarlu (1984b) observed reduction in nutrient drain by weeds in pigeon pea-based intercropping system. Cowpea with a good canopy cover was more efficient than sesame to control of weed. It was found that inclusion of green gram or cowpea as smother crops in sorghum/pigeon pea intercropping system suppressed the weed growth and proved as effective as compared to two hand weeding. Green gram was more efficient in initial stage, while cowpea was more efficient at later stages.

Higher Moisture Condition

In high productivity zones of Indo-Gangetic plain region of India, the rice-wheat cropping system is exhibited which decline factor productivity, deterioration in soil health and low use-efficiency. All the *kharif* cereals *viz.,* rice, maize, pearl millet, and sorghum are heavy feeders of N, P and K. however, opinions about the carryover effect of fertilizers from maize to wheat, although are to be controversial. The carry over effects are small and in some cases, emerge under conditions where maize yields are sub-optimal (Bhardwaj, 1978). Yields of Wheat after sorghum were 27 % lower in comparison with those obtained after fellow condition (Srivastava et al., 1974). Recently, Ghosh et al. (2004a) and Ghosh et al. (2004b) also claimed that drastic reduction in growth and yield of wheat after sorghum. Thus, 25% of additional nitrogen is recommended for wheat grown after pearl millet or sorghum. In general, grain yield of succeeding crop increased markedly when legumes preceded them as compared to those cereals preceded. Use of sorghum as the rainy season crop caused yield reduction in other crops also like pigeon pea (28% in intercropping and 4.6% in sequential cropping) and chickpea (36% for sequential cropping). Though, different legumes have the capacity to leave behind different amounts of N for use by the succeeding crop. Fodder legumes contribute higher than grain legumes for use by the succeeding crop. The carryover of N for succeeding cereal may be 60 to 120 kg in berseem, 75 kg in Indian clover, 75 kg in cluster bean, 35 to 60 kg in fodder cowpea, 68 kg in gram, 55 kg in black gram, 54 to 58 kg in groundnut, 50 to 51 kg in soybean, 50 kg in *Lathyrus,* and 36 to 42 kg in pigeon pea (Singh et al., 1988; Hegde and Dwivedi, 1993). Moreover, Yadav et al. (2003) noticed that yields of wheat following cowpea were significantly higher by 19-20%, compared with those having in rice. Similarly, wheat yields following soybean were significantly greater by 25% over those following sorghum (Ghosh et al., 2004a).

Competition in intercropping systems

Light

The individual yields of forage legumes and companion crops are generally not to be more in intercropping experiments than in monocroping. The decrease in biomass production has been attributed to competition for light, nutrients and moisture. Several researchers (Willey, 1979; Reddy and Willey, 1979; Baker and Yusuf, 1976) considered light is the most important factor in competition, particularly when the crops are of different durations grown together. However, efficient use of light can also be attained by spatial arrangements of multi-storey cropping with short and tall crops carefully, provided the short crops are modified to low light intensities. Light also has an important effect on the some species for reproduction. Jones and McCown (1983) mentioned that Caribbean stylo *(Stylosanthes hamata* cv. Verano) produced small seeds in an intercrop with maize due to its failure to attained flower in the shade of a full maize canopy (50,000 plants/ha in 75 cm rows), whereas *Alysicarpus vaginalis* produced 2000-4000 seeds/m^2.

Soil Moisture and Nutrients

Competition for water can be severe in the semi-arid areas is relatively dry years in the humid region. Although in a season when moisture was most limiting, yield of maize intercropped with alfalfa crop and lading clover was greatly reduced even with adequate N application (Kurtz et al., 1952). Growing crops with different rooting patterns, and which thus exploit different soil layers, would reduce competition for water and nutrients. Furthermore, According to Kurtz et al (1952), below-ground competition for moisture and mobile nutrients such as nitrate and competition for immobile nutrients, such as P, does not normally occur, except in some limited regions where the root systems of the intercrops are in actual contact is mostly limited to competition The use of a forage legume that can fix large amounts of N would reduce one of the major sources of competition. Different views have also been expressed contexting the relative significance of above and below-ground competition (Ready and Willey, 1979; Snaydon and Harris, 1979).

Minimizing Competition in Intercropping Systems

A decrease of 10 to 15% relative to the cereal monocrop, although may be acceptable to the subsistence farmer. Some agronomic package practices that can help minimize competition and raise the productivity of intercrops. In India Farmers will bear only small reductions in the yield of cereal due to intercropping crops, since cereal grain is the most priority among the Indian farmer are discussed below.

Time of sowing

The time of sowing is critical for optimal for cereal-legume production. The best time depends on the cereal and the legume needs to be determined experimentally. Mohamed-Saleem (1984) found that planting *Stylosanthes guianensis cv.* Cook or *S. hamata* cv. Verano on the same day as an unimproved sorghum variety abridged grain yield by over 70 %, but the reduction was fewer if the cereal was sown 3 weeks before the legume. In another study, it was noted that an medium-duration sorghum cultivar, SK 5912, sown on the same day as *Centrosema pascuorum, Alysicarpus vaginalis* and *Macroptilium lathyroides* did not significantly suffer yield reductions. However, the indication from the few time-of-planting studies is that sowing a legume simultaneously with a fast-growing cereal has no effect on cereal yield, but more work is required with different crop species for detailed study. Large-seeded legumes, such as lablab, which germinate comparatively fast, are likely to compete more with cereals if sown at similar time than small-seeded ones such as *Trifolium* and *Medicago* species.

Planting density: At high density (81 plants/m), stylo substantially reduced the grain yield of the rice intercrop (Shelton and Humphreys, 1975). Similar effect of high lupin rates on wheat yields have been observed by Gardner and Boundy (1983). In cereal legume intercrops it is important that the population of the cereal crop be as close as possible to its maximum monocrop population, and the density of the legume should not be so high as it decrease grain yield.

Planting pattern

Approaches that appear promising involves leaving 2 cereal stands per hill at wide spacing (0.3 m) and planting the intercrop legume on alternate rows. Apart from the time of sowing, it is also being necessary to manipulate planting patterns in order to sustained cereal yields. This system allows the cereal to be maintained at or near the optimum monocrop population and, if necessary, a third intercrop to be planed between the sorghum hills. Using the above technique, Mohamed-Saleem (1984) found that inter-row sowing of *Stylosanthes guianensis* reduced grain yield by about 10% compared with pure sorghum plots.

Thomas and Bennett (1975) compared broadcasting forage seeds with drilling on ridges or in furrows. They reported that drilling a mixture of silverleaf desmodium and Rhodes grass on ridges or in furrows after the first weeding in maize produced yields of maize similar to those achieved when the same quantity of forage seeds was broadcasted, but it significantly gave higher legume dry weight. Drilling in the furrow has the advantageous that a hand-operated planter can be successfully used.

CONCLUSION

In India, intercropping of maize with legume systems clearly has greatest potential to increase the sustainability of food production under low inputs in many parts. Whereas, some of the mechanisms by which they deliver benefits are understood, in general farmers require technical support because the new generation of farmers may not hold the know-how to grow arable crops as intercrops, although there is considerable potential to improve intercropping to achieve either greater yield with the same inputs, or sustained yield with abridged inputs based on new knowledge from both agronomy and environment, and finally interface between disciplines. Moreover, there is also a need to determine the optimum planting times and densities as well as the best planting patterns for major cereal - legume mixtures. The aim should be to maximize the yields of both intercrops. Fertilization schedules for promising cereal-legume combinations need to be determined. It is also important to emphasize the development of intercrops with maize cereal. Though, applying all of above approaches will need a better exchange of information among ecologists, soil scientist, environmental crop scientists, scientists, agronomists, microbiologist, and ultimately Extention workers for. Exploring attitudes to adopt, and developing wider cost/ benefit analyses, so that the full potential of intercropping as a sustainable intensification under different planting geometries in Western Uttar Pradesh can be realized.

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