INFLUENCE OF LEGUME CROPS AND FALLOWS ON FERTILIZER NITROGEN REQUIREMENT AND PRODUCTIVITY OF SUCCEEDING MAIZE—A REVIEW

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Received: 12-09-2011 Accepted: 31-12-2012

ABSTRACT

Maize being an exhaustive crop demands for higher fertilizer application, especially N fertilizer and the addition of nutrients through fertilizers is, however, far below the crop removal. Exploring low-cost agronomic practices is highly imperative in the present day agriculture to increase farmers' profitability and environmental safety. Further, while devising fertilizer N recommendations to a crop it is necessary to consider cropping sequence as a whole rather than that individual crop per se because the need for nutrients by a crop would vary depending upon the preceding crop type and its inputs usage. This review provides an update on the research undertaken on productivity and nitrogen requirement of maize as influenced by preceding cropping practices.

Key words: Crop sequence, Maize, Nitrogen.

INTRODUCTION

Maize (Zea mays L.) is an important staple food grain crop of the world next to wheat and rice. Growers’ interest towards maize has been increasing due to its high production potential and variety of industrial uses. Growing weird weather patterns and inadequate supply of water for cultivation of rice also shifting growers’ interest towards maize.

Productivity of a crop and its fertilizer need vary greatly with preceding crop and its practices in crop sequences. Increasing costs of nitrogenous fertilizers and growing consciousness towards safer environment have led to assess legume crops as an alternate source of N supply in crop sequences, as they fix up atmospheric N₂. Due to this mechanism of atmospheric N₂ fixation, legumes may deplete less soil N and contribute for better performance of succeeding crops. Contribution of legumes towards N economy in cereal-based cropping systems is well-known and the studies suggested that inclusion of grain legumes, particularly greengram, cowpea and groundnut were beneficial for improving productivity, profitability, N economy and soil fertility in maize. Legumes are widely recognized as builders of soil fertility and contribute substantial amounts of N for sustainability of cereal-based cropping systems. Inclusion of legumes increases soil fertility and consequently the productivity of succeeding cereal crops (Ghosh et al., 2007). Fodder or green manure legumes are more important N economizers than grain legumes (Gangwar and Sharma, 1994).

Exploring different agronomic practices to cut short N requirement of maize may reduce cost of cultivation and increase profitability. Retention of legume residues improves the N economy of the cropping system and enhances the crop productivity through many other potential benefits such as lower pest and disease incidence (Kirkegaard et al., 2008). The inclusion of legumes and stover incorporation improves the productivity of soil and the grain yield of subsequent non-legume crop owing to release of nitrogen and other growth promoting factors (Shivaran and Ahlawat, 2000). Incorporation of plant residues is a useful means of sustaining organic matter content and thereby enhance the biological activity, improve physical properties and nutrient availability (Palm et al., 2001).

Green manuring with annual leguminous crops like Sesbania aculeata is a widely investigated practice and found beneficial for realizing potential yields, N economy and improving soil fertility (Singh et al., 1991). This practice, however, is rarely

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followed by the growers because of poor economics and requiring additional inputs. On the other hand, dual purpose legumes such as greengram, cowpea and soybean provide direct economic produce as well as stover and residues with nodules which can mimic the effect of green manuring (Ojiem et al., 2006 and 2007 and Timsina et al., 2006).

**Effect of preceding crops on succeeding maize in crop sequences**

**Maize Growth**

From a long term field experiment on groundnut - maize cropping sequence, Rahim et al. (1994) reported significant increase in dry matter accumulation by maize with increasing succession of groundnut crop in sequence. Similarly, Singh et al. (2000) reported increase in maize growth parameters when it was intercropped with legumes than that when grown as sole crop on sandy loam soils of Uttar Pradesh. Tesfa et al. (2001) also reported increased maize growth parameters such as plant height and dry matter accumulation when it was rotated with sole legumes than that with fallow.

From field trials conducted simultaneously from 1998 to 2004 in two distinct agro ecological environments of West Africa, Franke et al. (2008) reported significant improvement in growth performance of maize in rotation with legumes (soybean, cowpea, *Stylosanthes guianensis*) than that with fallow. From Nigeria, Tanimu et al. (2007) also reported that maize crop succeeding legumes recorded higher plant height and dry matter accumulation when it was grown as sole crop on sandy loam soils of Uttar Pradesh. Tesfa et al. (2001) also reported similar results. Adiku et al. (2009) studied the effects of rotation of bare fallow, fallow residue management, legume fallows on maize growth and development on forest region of Ghana and reported significantly higher plant height and dry matter accumulation when maize followed elephant grass in rotation than that followed by bare fallow in rotation. Maize rotated with cowpea, mucuna or pigeonpea produced similar dry matter accumulation but was superior to bare fallow in rotation. Lelei et al. (2009) also studied the effects of legumes (*Crotalaria*, lablab, garden pea) and fallow on succeeding maize performance in dark reddish soils of Kenya and concluded that the incorporation of *Crotalaria*, lablab, garden pea residues resulted in higher accumulation of dry matter than that preceded by fallow or FYM incorporation. Studies of Sharma and Behera (2009) on sandy loams of New Delhi also revealed that all the growth parameters of maize improved from initial stages when grown in plots of summer legumes than in fallow. The beneficial effect of *Sesbania* on growth parameters of maize was better than that of greengram or cowpea. Further, increasing rates of N fertilizer improved the growth parameters in maize following legumes also.

**Maize Yield Attributes and Yield**

Singh and Kaushik (1987) on silty clay loam soils of Pantnagar reported that intercropping of legumes (blackgram, soybean, pigeonpea and clusterbean) in maize resulted in higher number of cobs ha$^{-1}$ and number of grains cob$^{-1}$ than that in sole maize or maize - wheat cropping sequence. Intercropping of maize with blackgram, soybean, pigeonpea and clusterbean with 50 kg N ha$^{-1}$ increased the maize grain yield by 3.7, 5.6, 3.4 and 4.5 q ha$^{-1}$, respectively, over sole maize grain yield (32.7 q ha$^{-1}$).

From a long term field experiment on groundnut - maize cropping system, Rahim et al. (1994) reported that the grain yield of maize increased from 3.9 t ha$^{-1}$ to 4.4 t ha$^{-1}$ with increasing succession of groundnut crop in sequence. Similarly, Ghosh and Singh (1996) on sandy loam soils, reported that maize grown after blackgram, greengram or cowpeas (grown for seed or fodder) recorded significantly higher number of grains cob$^{-1}$, grain weight cob$^{-1}$ and grain yield than that after maize itself continuously.

From the field trials conducted for five years on coarse textured soils, Bhal and Pasricha (2000) reported increase in maize yield by 30% in rotation with field pea than that with wheat and 35% increase when field pea residues also incorporated into the soil. The effect of field pea and residue incorporation was greater in the presence of fertilizer N.

Broadleaf bean found to contribute maximum increase in yield attributes and yield of succeeding maize on account of its greater ability for fixation of atmospheric N$_2$ (Martensson and Rydberg, 1996; Herridge and Rose, 2000).

Tesfa et al. (2001) also reported from Tanzania that number of grains cob$^{-1}$, cob weight
and grain yield of maize significantly increased where sole legumes preceded it in rotation. The highest grain yield (4.56 t ha\(^{-1}\)) was recorded from plots where sole Crotalaria preceded it. Yields of maize following canavalia, fallow and mucuna in rotation were only 3.88, 3.58 and 2.92 t ha\(^{-1}\), respectively.

Sidhu et al. (2003) evaluated the effects of wheat and summer moong residue incorporation with four levels of N (0, 60, 120 and 180 kg ha\(^{-1}\)) in summer moong - maize - wheat rotation in Punjab. Mean increase in maize yield succeeding the incorporation of summer moong residue and wheat residue + summer moong residue was 39% and 44%, respectively, over no residue incorporation and yield increased with the increase in N application irrespective of the residue incorporation. Similar results were also reported when maize was rotated with mucuna or cowpea from Nigeria (Franke et al., 2004) or rotated with groundnut than with fallow from sandy loam soils of sub humid Zimbabwe (Jerenyama et al., 2007).

From the field trials conducted in two locations in Nigeria, Franke et al. (2008) reported that yield of maize was the highest following S. guianensis cultivation (5.3 Mg ha\(^{-1}\)) than that following fallow (4.9 Mg ha\(^{-1}\)) and grain legumes (3.4 Mg ha\(^{-1}\)) at Ibadan location while at Zaria location, the results showed that maize cultivation after dual purpose soybean achieved the highest grain yield (4.3 Mg ha\(^{-1}\)) than that following fallow (2.5 Mg ha\(^{-1}\)).

Adiku et al. (2009) also investigated the effects of rotation of bare fallow, fallow residue management, legumes on maize growth and development in Ghana and reported that maize grain yield was higher when rotated with elephant grass (3.0 t ha\(^{-1}\)) than when rotated with fallow (1.0 t ha\(^{-1}\)). Maize rotated with cowpea, mucuna or pigeonpea produced similar grain yields (2.0 t ha\(^{-1}\)) but were superior to those rotated with fallow.

Lelei et al. (2009) studied the effect of legumes (Crotalaria, lablab and garden pea) and fallow on the performance of succeeding maize in dark reddish soils of Kenya and concluded that maize grain yield following lablab was significantly higher than that following Crotalaria, garden pea or fallow.

Sharma and Behera (2009) studied direct and residual effect of different legumes along with varying rates of N fertilizer on productivity, profitability and residual soil fertility in maize - wheat cropping system on sandy loams at IARI, New Delhi and reported significantly higher maize grain yield following legumes, Sesbania (3.52 t ha\(^{-1}\)), greengram (3.42 t ha\(^{-1}\)), cowpea (3.33 t ha\(^{-1}\)) than that following fallow (2.97 t ha\(^{-1}\)). Similarly, Yusuf et al. (2009) reported that maize following soybean or cowpea had higher grain yield of 1.2 and 1.3 fold than that following maize itself or fallow.

**Maize Responsiveness to Nitrogen Application**

Legumes are known to benefit the succeeding crop by their less dependence on soil N as they fix up atmospheric N\(_2\). Further, legume crop residues are richer in all nutrients than cereal crop residues with narrower C:N ratio (<30:1), which decompose rapidly and release N for uptake by succeeding crop (Balasubramanian and Nnadi, 1980 and Giller and Wilson, 1991).

From a long term field experiment on Ultisols, Rahim et al. (1994) reported that maize N requirement was reduced by 19 kg ha\(^{-1}\) to 56 kg ha\(^{-1}\) following groundnut in sequence.

Ghosh and Singh (1996) reported that maize grain yield was significantly higher following fodder cowpea or greengram with the application of 30 kg N ha\(^{-1}\) than that at higher N rates (60 and 90 kg ha\(^{-1}\)).

Tesfa et al. (2001) in Tanzania evaluated legume maize crop management systems and revealed that the maize response to N fertilizer was linear in continuous maize cropping and did not reach a maximum in the range applied N from 0 to 92 kg ha\(^{-1}\). Maize following legumes supplemented with fertilizer N increased maize grain yield from 6.7 to 10.9 t ha\(^{-1}\) but responded to fertilizer N upto 69 kg N ha\(^{-1}\). Similarly, Tripathi and Hazra (2002) reported forage maize response to fertilizer N upto 90 kg ha\(^{-1}\) only following green manuring of cowpea compared to that of 120 kg N ha\(^{-1}\) following fallow. In contrast, Ahlawat et al. (2005) recommended the application of 100 per cent recommended dose of fertilizer N to maize following chickpea in sequence. Jerenyama et al. (2007) on sandy loam soils of sub humid Zimbabwe reported that maize grain yields increased up to 0.7 t ha\(^{-1}\) following groundnut than
with maize itself and fertilizer N was saved to the extent of 64 kg ha\(^{-1}\) in maize following groundnut. Sharma and Behera (2009), however, reported from IARI that maize responded to lower levels of fertilizer N following Sesbania green manuring, cowpea and greengram crops. They reported a saving of fertilizer N to the extent of 57-67 kg ha\(^{-1}\) with Sesbania and 37 - 49 kg ha\(^{-1}\) with cowpea and greengram crops. In contrast, Yusuf et al. (2009) observed response of maize to levels of fertilizer N application whether or not maize followed legumes, maize or fallow. A few other researchers also observed such response of maize to N levels in crop sequences involving legumes or fallow (Sanginga et al., 2001, Yusuf et al., 2003 and Tanimu et al., 2007).

**Nutrient Uptake**

From a long-term field experiment on Ultisols Rahim et al. (1994) reported that in groundnut-maize cropping system, uptake of N by maize increased by increasing succession of groundnut in the system from 65.3 kg N ha\(^{-1}\) immediately after one groundnut crop to 87.7 kg N ha\(^{-1}\) after three successive groundnut crops in the system.

Tripathi and Hazra (2002) also reported increase in N, P and K uptake by forage maize in succession with cowpea green manuring or cowpea grown for fodder.

Ladha et al. (2005) reported no residual effects of N fertilization in cereal – based cropping systems, but when N applied along with organics or mulching materials residual effect on succeeding crops was noticed due to formation of organo – mineral complexes, which are held for a greater period in soil.

Tanimu et al. (2007) from Nigeria reported that the N, P and K content of maize succeeding legumes increased significantly with increasing rates of N fertilizer compared to that of fallow. Further, incorporation of organic matter found to enhance the nutrient balance by serving as a nutrient reservoir in the soil. Lal (1979) and Bin (1983) also reported such findings.

Sharma and Behera (2009) reported that N uptake by maize grain (53.1-56.4 kg ha\(^{-1}\)) increased significantly following summer legumes compared with that after fallow (47.1 kg ha\(^{-1}\)). Similarly, Yusuf et al. (2009) reported from Nigeria that the maize uptake of N was lower following maize or fallow (61 kg ha\(^{-1}\)) in sequence than that following either soybean (68 kg ha\(^{-1}\)) or cowpea (83 kg ha\(^{-1}\)).

**EFFECT OF GREEN MANURING ON MAIZE PERFORMANCE**

**Growth, yield attributes and yield**

Rachpal et al. (1982) conducted an experiment on loamy sandy soils at Fathepur and reported that the plant height and dry matter production of maize was significantly higher with the incorporation of different green manure crops like cowpea, clusterbean and Sesbania than that of fallow, irrespective of level of N applied.

From Ludhiana, Singh and Brar (1985) also observed that the maize growth parameters like plant height and dry matter accumulation were significantly increased with the incorporation of 20 t ha\(^{-1}\) phytomass of cowpea than that of incorporation of 20 t FYM ha\(^{-1}\). Similarly, Bhandari et al. (1989) reported that when green manure crops like cowpea and Sesbania aculeata of 45-50 days old were incorporated fifteen days prior to maize resulted in significant increase in maize growth parameters and supplemented fertilizer N by 60 kg ha\(^{-1}\).

Grewal et al. (1992) reported from Ludhiana that in sandy loam soils maize - wheat cropping sequence, green manuring in situ of cowpea or prickly sesban at 45 days age before maize sowing significantly improved the maize plant height and dry matter accumulation.

Palled et al. (1997) conducted an experiment on red sandy soil at Raichur and reported increase in growth parameters of maize green manured with subabul loppings along with 100% RDN application than that with either of these two.

Pathak et al . (2002) studied the effect of FYM, rice straw and green karanj leaves in maize - wheat sequence on loam soils of Ranchi and reported that plant height, leaf area index, dry matter accumulation in maize were maximum with the FYM application than that with the other two organic sources.

Tiwari et al. (2004) conducted an experiment at Maharana Pratap University of Agriculture and Technology, Udaipur, in maize -
wheat cropping system, and reported that the plant height and growth characters of maize were significantly increased due to incorporation of green manures Sesbania cannabina and Sesbania rostrata than that with no green manuring. Similarly, from black clay soils of Dharwad, Sujatha et al. (2008) reported that sunnhemp green manuring to maize recorded significantly higher plant height, leaf area index, dry matter accumulation than that of cowpea green manuring.

Sharma et al. (2009) reported from silty clay loam soils of Dehradun that growth attributes of maize were significantly superior with live mulching of sunnhemp + Leucaena to that of no mulching.

**Yield Attributes and Yield**

Rachpal et al. (1982) studied the effect of green manures in maize - wheat rotation and reported higher grain yield of maize following incorporation of cowpea (3.82 t ha\(^{-1}\)) and clusterbean (3.76 t ha\(^{-1}\)) than that of fallow (3.11 t ha\(^{-1}\)). Similarly, Singh and Brar (1985) reported from Ludhiana that the maize grain yield following the incorporation of 20 t ha\(^{-1}\) phytomass of cowpea (3.51 t ha\(^{-1}\)) was higher than that following the application of 20 t ha\(^{-1}\) FYM (3.03 t ha\(^{-1}\)).

From an experiment conducted at Ludhiana, Grewal et al. (1992) revealed that in maize - wheat cropping sequence, green manuring in situ with cowpea or prickly sesban at 45 days age before maize sowing significantly improved the productivity of maize. Similarly, Palled et al. (1997) reported from red sandy soil of Raichur that green manuring with subabul loppings in maize with 100% RDN application recorded maximum number of grains cob\(^{-1}\), grain weight cob\(^{-1}\) and test weight than those with either of them.

Dasaraddi (1998) observed that among different legumes viz., sunnhemp, dhaincha, cowpea, black soya and horsegram grown as intercrops for green manuring in 1:2 row proportion and incorporated at 50 DAS in maize field, dhaincha and sunnhemp produced significantly higher biomass and N turnover for incorporation and improved the yield attributes and yield of maize.

Nooli (2001) reported that maize yield attributing characters and yield were relatively higher when maize was intercropped with legume green manures like cowpea, horsegram, fieldbean, greengram, sunnhemp, dhaincha and black soya on black soils of UAS, Dharwad. Similarly, Tripathi and Hazra (2002) revealed from an experiment at Indian Grassland and Fodder Research Institute, Jhansi (U.P) that green and dry fodder yields of maize increased significantly following green manuring of cowpea than following no green manuring (fallow).

On sandy loams of Udaipur, Tiwari et al. (2004) recorded higher yields of maize with green manuring of Sesbania cannabina or Sesbania rostrata 2.87 and 2.77 q ha\(^{-1}\), respectively, over the control (no green manuring). Similarly, Balkcom and Reeves (2005) reported increase in maize grain yields by 1.2 t ha\(^{-1}\) with sunnhemp green manuring.

From black clay soils of Dharwad, Sujatha et al. (2008) reported that sunnhemp green manuring in maize increased cob length, cob girth, number of grains per cob of maize grown with sunnhemp green manuring than that of cowpea green manuring. Similarly, on silty clay loam soils of Dehradun Sharma et al. (2009) recorded significantly the highest maize grain yield (2.36 t ha\(^{-1}\)) and stover yield (5.15 t ha\(^{-1}\)) with live mulching of sunnhemp + Leucaena than no mulching (2.05 t ha\(^{-1}\) and 4.53 t ha\(^{-1}\), respectively).

**Maize Responsiveness to Nitrogen Application**

From loamy sand soils of Fatehpur, Rachpal et al. (1982) reported that incorporation of cowpea or cluster bean followed by maize with application of 50 kg N ha\(^{-1}\) recorded similar maize yields as that of Sesbania green manuring with 75 kg N ha\(^{-1}\) or with 125 kg N ha\(^{-1}\) with no green manuring (fallow). Similarly, Singh and Brar (1985) reported from loamy sand soils of Ludhiana, similar maize grain yield either with incorporation of 20 t ha\(^{-1}\) phytomass of cowpea or with 120 kg ha\(^{-1}\) fertilizer N.

Sharma and Mitra (1988) reported that incorporation of Sesbania aculeata or sunnhemp before maize planting saved fertilizer N upto 45-60 kg ha\(^{-1}\) on acid lateritic soil of Kharagpur. Similarly, Bhandari et al. (1989) in a study on nitrogen economy through green manuring in maize on cultivators fields of Ropar and Patiala districts reported that green manuring with cowpea or Sesbania aculeata (45 to 50 days old) prior to sowing of maize substituted for nearly 60 kg ha\(^{-1}\) of fertilizer N needed by the succeeding maize.
Grewal et al. (1992) in their study on combined use of green manure and fertilizer N on the productivity of maize-wheat system at Ludhiana noticed significant improvement in maize yield with cowpea or dhaincha green manuring with 60 kg ha\(^{-1}\) fertilizer N (3.74 t ha\(^{-1}\)) than that with 120 kg ha\(^{-1}\) fertilizer N without green manuring (2.1 t ha\(^{-1}\)). Similarly, Sur et al. (1993) reported from Ludhiana that maize yield was higher with green manuring than without green manuring at all the levels of fertilizer N applied. The persistence of yield differences at higher levels of fertilizer N they attributed for improvement in soil environment in terms of physical, chemical and biological properties due to green manuring.

Jerenyama et al. (2000) reported from loamy sands of Zimbabwe legume intercrops in maize could reduce fertilizer N needs of subsequent maize by 18 to 36 kg ha\(^{-1}\). Similarly, Tripathi and Hazra (2002) reported from an experiment conducted at Indian Grassland and Fodder Research Institute, Jhansi (U.P.) that cowpea green manuring and cowpea grown for fodder could reduce fertilizer N need of succeeding maize crop from 120 to 90 kg ha\(^{-1}\).

Tiwari et al. (2004) also reported from sandy loams of Udaipur that green manuring with Sesbania cannabina and Sesbania rostrata with 90 kg N ha\(^{-1}\) to maize crop increased grain yield by 1069 and 1049 kg ha\(^{-1}\) over control, respectively. Green manuring either of the Sesbania species + 30 kg N ha\(^{-1}\) gave maize yield equivalent to that obtained with 90 kg N ha\(^{-1}\) alone indicating green manuring influence 60 kg ha\(^{-1}\) of fertilizer N. On similar lines, Balkcom and Reeves (2005) reported fertilizer N replacement value for sunnhemp green manuring @ 58 kg ha\(^{-1}\) in maize cultivation.

Sujatha et al. (2008) reported that incorporation of sunnhemp as green manure along with application of 100 per cent RDN recorded significantly higher grain yield (6.31 t ha\(^{-1}\)) and stover (10.61 t ha\(^{-1}\)) over lower rates of N application on black soils. Similarly, Sharma et al. (2009) observed maize response to fertilizer N at all the rates they applied (0 to 90 kg N ha\(^{-1}\)) even with sunnhemp or Leucaena mulching at Selaki, Dehradun.

**Nutrient Uptake**

Jerenyama et al. (2000) reported increasing N uptake by maize with increased level of N application upto 60 kg ha\(^{-1}\) only when maize was intercropped with legumes and upto 120 kg N ha\(^{-1}\) application when maize was grown as sole crop. Similarly, Tripathi and Hazra (2002) noticed significant increase in N uptake by maize with the application of fertilizer N upto 90 kg ha\(^{-1}\) following green manuring of cowpea and upto 120 kg N ha\(^{-1}\) following fodder cowpea or fallow. Tiwari et al. (2004) also recorded significant increase in N uptake (38 %) of maize when it was green manured than that without green manuring. A few other researchers also reported increase in N uptake by maize with green manuring (Ladha et al., 2005; Sujatha et al., 2008 and Sharma et al., 2009).

**EFFECT OF NITROGEN ON MAIZE**

**Maize Growth**

Yadav et al. (1982) reported from sandy loam soil of Chhindwara, that plant height, dry matter production in maize increased significantly with increase in N application up to 180 kg ha\(^{-1}\). Further, they reported decrease in number of days taken to reach silking stage with increasing rate of N application.

Sharma (1983) also reported significant increase in the plant height and number of leaves per plant with each successive increase in N level on sandy loam soil of IARI, New Delhi. Similarly, Jolly et al. (1987) stated that increase in level of N application from 90 to 150 kg ha\(^{-1}\) has increased the plant height and dry matter of maize on loamy-sand soils of Ludhiana. Similarly, Dhillon et al. (1987) from Ludhiana and Prasad et al. (1987) from Pusa also reported increase in maize growth with increasing levels of N application from 0 to 120 kg ha\(^{-1}\) and 0 to 150 kg ha\(^{-1}\), respectively. A few others also reported significant response of maize to N application up to 120 kg N ha\(^{-1}\) on light soils (Bangarwa et al., 1988; Reddy et al., 1988; Munuswamy et al., 1990; Walia et al., 1991 and Shanti et al., 1997).

In contrast, on sandy loam soils, Singh et al. (1993) reported significant maize growth response upto 150 kg N ha\(^{-1}\) from Hisar, Kaul et al. (1994) upto 175 kg N ha\(^{-1}\) from Ludhiana and Padmaja et al. (1999) upto 150 kg N ha\(^{-1}\) from Bapatla. Further, Kumar and Bangarwa (1997) reported that leaf area index, dry matter accumulation increased significantly even upto 240 kg N ha\(^{-1}\).
From heavy soils of Nigeria, Iremiren et al. (1997) reported substantial increase in vegetative growth and early silking with increasing rates of N application up to 150 kg ha\(^{-1}\). Patel et al. (1999) also revealed that maize plant height and dry matter accumulation increased with the increase in N levels from 80 to 120 kg ha\(^{-1}\). Similarly, Shivay and Singh (2000) reported significant increase in plant height and dry matter accumulation with increase in the level of N application from 0 to 120 kg ha\(^{-1}\) on silty clay loam soil of Pantnagar. Gokmen et al. (2001) also reported increase in plant height and decrease in days to reach tasseling with increased level of N application up to 100 kg ha\(^{-1}\).

Regardless of soils and regions, a few researchers (Silva et al., 2000; Singh et al., 2003; Jehan et al., 2006; Omraj et al., 2007; Amujoyegbe et al., 2007 and Ahmed et al., 2009) reported increased growth parameters and improvement in chlorophyll content, leaf area and decrease in the days to reach silking with increasing rate of N application.

### Maize Yield Attributes and Yield

Yadav et al. (1982) reported from sandy loam soil of Chhindwara that number of cobs and yield were increased significantly with increase in N application up to 180 kg ha\(^{-1}\). Similarly, Dhillon et al. (1987) reported increase in yield attributing characters and grain yield with increasing rate of N application up to 120 kg ha\(^{-1}\) on sandy loam soils of Ludhiana. Panchanathan et al. (1987) from Coimbatore, Prusty et al. (1987) and Nimje and Seth (1988) from IARI, New Delhi, Walia et al. (1991) from Ludhiana and Gaur et al. (1992) from Udaipur reported similar results.

In contrast, Jolly et al. (1987) from Ludhiana, Bangarwa et al. (1988) from Hissar, Sharma et al. (1991) from Ludhiana and Singh et al. (1993) from Hissar noticed similar increase in maize yield attributes and grain yield but up to 150 kg N ha\(^{-1}\) application on similar type of soils. Further, Kaul et al. (1994) reported increase in maize yield up to 175 kg N ha\(^{-1}\) application on sandy loam soils of Ludhiana. Kumar and Bangarwa (1997) reported increase in grain and stover yield even up to 240 kg N ha\(^{-1}\) from sandy loams of Hissar.

Thanki et al. (1988) reported from heavy clay soils of Navasari that increase in maize yield attributes and grain yield was up to 180 kg N ha\(^{-1}\) application. Similarly, Khot et al. (1993) reported increase in maize yield attributes and yield up to 200 kg N ha\(^{-1}\) on medium deep soil of Rahuri.

Irrespective of the soils and regions, a few researchers (Shanti et al., 1997; Padmaja et al., 1999; Paliwal et al., 1999; Silva et al., 2000; Singh and Totawat, 2002; Jehan et al., 2006 and Ahmed et al., 2009) reported increase in yield attributes and maize grain yield with increasing rate of N application.

### Nutrient Uptake

Prasad et al. (1987) reported higher nutrient uptake by maize with increase in levels of N application from 0 to 150 kg ha\(^{-1}\) from their experiment on calcareous sandy loam soil of Pusa.

Baskaran et al. (1992) reported increased NPK uptake by maize with increase in rate of N application at all the growth stages of maize. Selvaraj and Irutharaju (1995) also reported from clay loam soil of Coimbatore increase in the N, P and K uptake by maize with increased level of N application up to 175 kg ha\(^{-1}\). Similarly, Shivay et al. (1999) and Shivay and Singh (2000) reported increase in N uptake with increase in rate of N application from 0 to 120 kg ha\(^{-1}\) on silty clay loam of Pantnagar. Singh and Totawat (2002) also noticed increased uptake of major (N, P and K) and micro nutrients (Zn, Fe, Mn and Cu) by maize with increase in level of N application on similar type of soil. A few researchers (Padmaja et al., 1999; Hussaini et al., 2008 and Ahmed et al., 2009) reported increase in nutrient uptake by maize with increasing rate of N application.

### Rice fallow maize

Sarkar et al. (2000) reported that rice maize sequence was more profitable than any other rice based cropping systems. Similarly, Gangawar et al. (2006) pointed out that rice maize system was a highly productive system than rice pulse system.

Mukundan et al. (2009) on sandy clay loams reported that zero tilled maize with paraquat application @ 1.5 kg a.i ha\(^{-1}\) in rice fallows would be effective and the performance of rice maize system in terms of total productivity and profitability were far higher (108.5 q ha\(^{-1}\)) of rice equivalent yield than rice pulse sequence (53.5 q ha\(^{-1}\)) of rice equivalent yield.
Bharathi et al. (2010) in a on farm study in Guntur district reported that incremental nitrogen levels had significant influence on yield and yield attributes of maize in rice fallows. Maximum grain yield and stover yield was recorded at 300 kg N ha\(^{-1}\) and was at par with 240 kg N ha\(^{-1}\). Highest benefit cost ratio was recorded with 240 kg N ha\(^{-1}\) and was 4% more than 300 kg N ha\(^{-1}\) and 10.9% more than 180 kg N ha\(^{-1}\).

Bharathi et al. (2011) reported that maximum grain yield of maize in rice fallows was recorded when first split dose of fertilizer was applied as farmers method at 15 days after sowing followed by 2\(^{nd}\) and 3\(^{rd}\) split applications as placement (7826 Kg ha\(^{-1}\)) and was on par with the treatment where first split dose of fertilizer was applied as farmers method at 15 days after sowing followed by 2\(^{nd}\) and 3\(^{rd}\) split applications as broadcasting (7751 Kg ha\(^{-1}\)) and were significantly superior to application of all the splits as placement (7368 Kg ha\(^{-1}\)) and broadcasting (7332 Kg ha\(^{-1}\)).

**ECONOMICS**

Shashidhara (1986) observed that inclusion of cowpea or horsegram in sequential cropping system especially for green manure purpose recorded higher yield of succeeding fingermillet but the gross returns were not high with green manuring system as green manure crop by itself did not bring any additional returns unlike fodder crops.

Angels and Prager (1989) noticed the positive effect in the cropping system with green manuring on the net returns and financial returns in maize-legume production system. Mulik et al. (1989) observed that higher net returns were obtained in the greengram - rabi sorghum cropping sequence as compared to kharif fallow-rabi sorghum. Rajodh et al. (1994) obtained higher monetary returns with sunnhemp green manuring in wheat crop.

Dasaraddi (1998) reported that in situ incorporation of legumes in maize - safflower cropping system recorded higher net returns and B:C ratio with maize + dhaincha, maize + sunnhemp and maize + cowpea intercropping succeeded by safflower with 20 or 40 kg N ha\(^{-1}\).

Hebbi (2000) observed that green manuring coupled with 50 or 25 kg N ha\(^{-1}\) to rabi sorghum increased the gross returns, net returns and B:C ratio over green manuring alone.

Itnal and Palled (2001) obtained maximum B:C ratio in sunnhemp green manuring with 50% RDN application in maize crop.

Gupta and Tripathi (2001) noticed that sunnhemp grown as green manure in rice - wheat cropping system did not affect the yield of rice while the yield of wheat was enhanced up to 43% with higher net returns and B:C ratio.

Nooli (2001) reported monetary advantage with maize + dhaincha and maize + sunnhemp succeeded by safflower than that with maize-safflower cropping system without green manuring.

Franke et al. (2004) reported that legume - maize cropping systems in comparison with full season maize, the use of cowpea followed by maize improved the productivity as well as economic returns of the cropping system, while the use of velvet bean resulted in poor overall productivity of the system. Viability of green manure based system depends on externalities and internalities.

Cherr et al. (2006) observed that green manure based system may provide alternatives to current approaches to crop production, however, the use of green manure may not be economically justified without the provision of multiple services such as nutrient supply, pest and weed control and improvement of soil characteristics for crop production.

Channabasavanna et al. (2007) from Siriguppa reported that green manuring with sunnhemp and application of recommended fertilizers in maize recorded maximum net returns and B:C ratio.

Sharma and Behera (2009) recommended that cultivation of dual purpose legumes during summer was a better option than Sesbania green manuring or fallow for improving productivity, profitability, N economy and soil fertility, leading to sustainability of maize - wheat cropping system in the Indo - Gangetic plains.
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