INTEGRATED NUTRIENT MANAGEMENT STRATEGIES FOR INCREASING ANNUAL FORAGE CROPS PRODUCTIVITY—A REVIEW

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SUMMARY

The scope of increasing the area cultivated for forages is rather limited, because of mounting pressure and preferential need for food and commercial crops. Hence, fodder production has to be increased per unit area per unit time. In recent years, there has been adverse effect of continuous and indiscriminate use of inorganic fertilizers on deterioration of soil structure, soil organic matter, increase in salinity, sodicity, increased soil pollutants, reduced soil health, hazards of pests and diseases and environmental pollution. Judicious use of manures and fertilisers in integrated manner is best alternative for maintaining crop productivity, while maintaining soil fertility status in forage crops. Integrated nutrient management (INM) improves crop productivity and soil fertility status rather than mineral fertilizers alone. Most of the research findings reviewed in this review indicated that among the integrated nutrient management combinations, application of chemical fertilizers integrated with organic manures in equal proportion improved sustainable forage productivity, nutrient uptake and soil nutrient status. Use of organic manures has been found to be promising in arresting the decline in productivity through correction of deficiency of secondary and micronutrients and influencing the physical and biological properties of soil. Combined application of inorganic fertilizers with different sources of organic manures in different proportions has significant role to boost forage productivity, improve nutrient uptake by plants and maintain soil nutrient status in forage-based cropping systems. Keeping these points in view, the literature pertaining to the nutrient management in different forage crops to obtain higher biomass production and good quality fodder has been reviewed.

Key words : Forage crops, INM, fodder yield, quality

Country faces regional and national deficit of green fodder, dry crop residues and feeds and the projections show a further demand increase by 2030 due to changing food habits and more dietary reliance on livestock and its products (Anonymous, 2011). The major annual forage crops are sorghum, maize, pearl millet, barley, oats, cowpea, lucerne and berseem. Use of high analysis fertilizers in imbalance and indiscriminate manner had developed many problems of soil organic matter, increase in soil salinity, sodicity, soil pollutants and hazards of pests and diseases (Chakraborti and Singh, 2004). To meet out the fodder demand, higher doses of inorganic fertilizers are applied which is uneconomical for fodder production and indiscriminate and continuous use of high amount of chemical fertilizers had deleterious effect leading to decline in productivity due to limitation of one or more micronutrients. Integrated plant nutrient management (INM) is the combined use of mineral fertilizers with organic resources such as cattle manures, crop residues, urban/rural wastes, composts, green manures and biofertilizers (Antil, 2012). Integrated nutrient management is flexible approach to minimise the use of chemical fertilizers but maximise their use efficiency and farmers’ profit. INM involving a combination of fertilizers, organic manures and biofertilizers is essential to sustain crop production, preserve soil health and biodiversity. The advantage of combining organic and inorganic sources of nutrients in integrated nutrient management has been proved superior to the use of each component separately (Palaniappan and Annadurai, 2007). The research findings on integrated nutrient management strategies for increasing annual forage crops productivity are reviewed.

Nutrient Management in Annual Forage Crops

The major annual forage crops are sorghum,
maize, pearl millet and cowpea which are mainly grown in kharif season and barley, oats, lucerne and berseem in rabi season.

Maize

Balanced application of NPK fertilizers with FYM and lime improved sustainable crop productivity and growth of maize (Dasog et al., 2012; Dutta et al., 2013). Many workers reported that integrated nutrient management practices significantly improved macro and micronutrient status of soils in maize cropping system. Balanced application of NPK fertilizers with FYM or agricultural wastes improved the soil fertility status in addition to increase in maize yield (Kemal and Abera, 2015). Karki et al. (2005) conducted an experiment at Indian Agricultural Research Institute, New Delhi on maize and reported that application of 120 kg N+10 t FYM per ha produced significantly higher plant height and dry matter production per plant over rest of the treatment combinations. Similarly, Kumar et al. (2005) conducted an experiment on maize at same location and reported that application of 120 kg N+26.2 kg P2O5+33.2 kg K2O per ha combining with 10 t FYM per ha yielded significantly higher plant height and leaf area index over chemical fertilizers alone. After 20 years of experimental study, at Kathalagere, India, Sathish et al. (2011) concluded that higher maize yields were recorded with application 50 per cent N through FYM and 50 per cent NPK through inorganic fertilizers. Application of 50 per cent organic manure (poultry and farm yard manure) along with 50 per cent nitrogen from urea resulted in higher yield and yield components compared to either organic or mineral nitrogen alone. Application of mineral N and 50 per cent poultry manure produced higher ear length, grains per ear, grain and biological yields of maize (Ali et al., 2012). Sarwar et al. (2012) at NARC, Islamabad revealed that substitution of 25 or 50 per cent N with FYM+4 kg Zn/ha performed better grain and straw yield than 100 per cent N (120 kg/ha) from chemical fertilizers alone. Maximum maize grain yield (5.18 t/ha) was obtained with 75 per cent chemical fertilizer (CF)+25 per cent farm yard manure (FYM) and 4 kg Zn/ha, although it was statistically similar with application of 50% CF+50 per cent FYM or 4 kg Zn/ha or 75 per cent CF+25 per cent FYM and 8 kg Zn/ha. 100 per cent NPK fertilizers produced highest grain and biological yields of maize over the 50 per cent NPK treatment. However, FYM with 50 per cent of recommended NPK was statistically at par with those receiving 100 per cent NPK fertilizers (Ahmad et al., 2013). The highest grain and stover yields (8.0 and 8.9 t/ha, respectively) of maize were recorded by the combined applications of 60 kg N/ha from poultry manure and mineral fertilizer at 60-40-40 kg/ha NPK compared to the unfertilized treatment which recorded the lowest grain and stover yields of 2.10 and 4.30 t/ha, respectively (Quanshah, 2010). In other study, poultry manure alone or in combination of 25 per cent NPK from chemical fertilizer+75 per cent from poultry manure increased yield of maize by 579 per cent, while 50 per cent NPK+50 per cent poultry manure increased yield by 499 per cent, respectively, over the unfertilized one. The author generally ranked the effects of INM on growth and yield of maize as poultry manure alone 25 per cent NPK+75 per cent poultry manure > 50 per cent NPK+50 per cent poultry manure > 75 per cent NPK+25 per cent poultry manure > 25 per cent NPK+75 per cent compost > compost alone > 50 per cent NPK+50 per cent compost > 75 per cent NPK+25 per cent compost > NPK alone > unfertilized plot (Hossain et al., 2012). The poultry and farm yard manure along with urea at equal proportion resulted in higher yield and yield components of maize than sole organic or mineral nitrogen (Ali et al., 2012). Cheema et al. (2010) found that by applying 50 per cent N through poultry manure and remaining 50 per cent through inorganic fertilizers produced maximum grain yield of maize (5.6 t/ha), harvest index (24.91%) and grain weight per cob (68.98 g) compared to unfertilized treatment which gave the lowest harvest index (15.71%), grain yield (2.40 t/ha) and weight per cob (44.53 g). INM including vermicompost showed best results in yield parameters of maize like number of grains per cob, weight of the cob, 100-seed weight and yield (Kannan et al., 2013). The treatment 75 per cent (NPK)+FYM (4.5 t/ha)+biofertilizer (Azotobacter+Phosphate solubilizing bacteria (PSB) proved to be superior as compared to other combinations including unfertilized control in increasing cob yield with and without husk, fodder yield and green biomass yield (Rasool et al., 2015). Increase in fodder yield with integrated nutrient management was also reported by Das et al. (2008). Puri and Tiwana (2008) at Ludhiana reported maize fertilized with 25 t FYM/ha and 100 kg N/ha produced palatable and nutritious fodder in large quantities. Kalhapure and Dhonde (2013) reported maximum B : C ratio (1.30) which was also observed in jointly use of 25 per cent RDF, compost, biofertilizers and green manuring and it was followed by application of 100 per cent RDF (1.26) which was responsible for
deterioration of nutrient status of soil. Ghaffari et al. (2011) reported that the quality parameters of maize (oil contents) were significantly improved by foliar application of multi-nutrients solution. However, recommended dose of fertilizer in addition to single spray of multi-nutrients was economical.

Sorghum

Sorghum (Sorghum bicolor L.) is one of the best crops to obtain high forage production with good nutritive value for animals. The nutrient requirement of sorghum grown for fodder is quite high which is mainly supplemented through inorganic fertilizers and partially through organic sources. The integration of organic and inorganic sources may help in minimizing the cost of chemical fertilizers; and improving crop performance and soil fertility (Swarup, 1998). Judicious use of FYM with chemical fertilizers improved soil physical, chemical and biological properties and improved the sorghum productivity (Sharma et al., 2007). Tiwana and Chaudhary (2009) at Ludhiana during 2007 and 2008 also found that application of 100 per cent RDF+25 kg Zn/ha recorded highest green fodder. The 100 per cent RDF alone or along with Zn and INM treatments increased the green fodder yield and dry matter yield of sorghum significantly over control. Yadav et al. (2012) at Udaipur reported that RDF recorded significantly higher plant height, dry matter accumulation at all stages of crop growth, yield attributing characters, yield, gross and net returns and B : C ratio of crop over rest of the treatments. Yadav et al. (2007) at Anand observed that application of 75 kg N through urea+25 kg N/ha through farm yard manure (FYM) increased dry matter yield and crude protein yield of sorghum by 18.6 and 20 per cent, respectively, over application of 100 kg N/ha through urea. Tripathi et al. (2007) at Jhansi reported that application of sulphur (40 kg/ha), Zn (20 kg/ha) and Mn (10 kg/ha) along with recommended NPK to sorghum gave significantly higher dry fodder yield by 16.5 per cent over NPK alone (32.52 t/ha green and 8.48 t/ha dry fodder). Yadav et al. (2010) reported that application of 75 kg N/ha through chemical fertilizer+25 kg N/ha through FYM or castor cake along with the combined inoculation with Azotobacter chroococcum (ABA-1)+Azospirillum lipoferum (ASA-1) recorded significantly higher green forage yield and crude protein content of forage sorghum in sandy loam soils under middle Gujarat agro-climatic conditions. Duhan (2013) reported substitution of 100 per cent recommended dose of nitrogen through FYM increased the fodder yield of sorghum from 41.11 to 56.97 q/ha over absolute control. Application of 100 per cent recommended dose of nitrogen through FYM also increased the uptake of N, P and K by sorghum significantly from 62.25 to 77.48, 7.40 to 10.82 and 53.44 to 85.46 q/ha, respectively, over absolute control. Afzal et al. (2013) also reported the increase in growth of fodder sorghum with the increase in nitrogen levels. Tiwana and Chaudhary (2009) reported that highest IVDMD (59.2%) was obtained with 75 per cent RDF+25 per cent N through FYM or vermicompost than 50 per cent RDF+50 per cent N through FYM or vermicompost and 100 per cent RDF alone or with Zn. Application of 75 per cent dose of recommended nitrogen through inorganic sources+25 per cent through vermicompost significantly improved the growth, productivity and fodder quality over the control at Pant Nagar. The highest green fodder yield (52.8 t/ha), dry matter yield (13.5 t/ha), total crude protein yield (0.92 t/ha), digestible dry matter yield (6.6 t/ha), juice yield (9,910 kilo litre/ha), sugar yield (0.91 t/ha) and calculated ethanol yield (2,762 kilo litre/ha). Fodder quality parameters like juice percentage (26.2), dry matter content (25.6%), digestibility (48.7%) and neutral detergent fibre content (61%) were recorded with application of 75 per cent recommended dose of N through inorganic sources+25 per cent through vermicompost (Singh et al., 2015).

Pearl millet

Pearl millet (Pennisetum glaucum L.) is a valuable source of green and dry fodder/stover in dry tracts of South-West Haryana, Gujarat and Rajasthan. Pearl millet crop can be sustained by the application of balanced use of nutrients to the crops through integration of organic manures and fertilizers. Application of 60+40 kg/ha of N+P2O5 along with 10 t FYM/ha and biofertilizer gave significantly higher grain yield and N, P uptake by pearl millet than control and FYM (5 or 10 t/ha)+biofertilizers use (Kumar et al., 2014). Choudhary and Gautam (2007) at IARI, New Delhi reported that application of FYM @ 10 t/ha to pearl millet enhanced total green forage and dry matter yield. Inoculation of pearl millet seed with biofertilizer significantly increased the yield over without inoculation (Golada et al., 2010). The maximum plant height (239.2 cm), number of tillers
(31.7), green fodder yield (376.0 q/ha) and dry matter yield (108.9 q/ha) were obtained with 90 kg N/ha as compared to lower levels (0, 30 and 60 kg) of nitrogen (Singh et al., 2012a). Application of farmyard manure in combination with biofertilizer (Azospirillum + PSB) to pearl millet showed significant increase in growth parameters in terms of plant height (150.3 and 175.2 cm), number of leaves per plant (455.5 leaves in hybrid and 77.9 leaves in composite), tiller thickness (4.38 in hybrids and 5.16 in composites) and highest green fodder yield of 70.7 t/ha in hybrids and 87.2 t/ha in composites compared to control with 54 t/ha in hybrids and 67.3 t/ha in composites (Basanthi et al., 2012a). Application of 20 kg ZnSO₄/ha as basal or 10 kg ZnSO₄ as basal+0.5 per cent as foliar spray at 30 days after sowing of the crop produced significantly superior earheads, grain and fodder yields (fresh and dry) of pearl millet than without zinc application (Kumar et al., 2012a). Kumar et al. (2012b) resulted that application of 50 per cent N through FYM along with 50 per cent NPK through chemical fertilizers in pearl millet and 100 per cent NPK through chemical fertilizers in wheat produced highest yield and had beneficial effect on gross returns, net returns and B : C ratio.

Oat

Oat (Avena sativa L.) is widely grown for green fodder because of its high growth, good palatability and highly nutritious nature. Line sown crop along with application of 80 kg N/ha recorded highest forage yield, net returns and benefit : cost ratio. Increase in forage yield with increased nitrogen levels was attributed to tall plants, more number of shoots and wide leaf : stem ratio (Sharma and Bhunia, 2001). Application of 50 per cent recommended NPK (40 : 20 : 0 kg/h) fertilizer+vermicompost+FYM each at 5 t/ha recorded significantly higher yield of oats. Similarly, application of 150 kg N/ha along with 40 kg P/ha and dual inoculation of seed with Azotobacter chroococcum (N fixer) + Pseudomonas striata (phosphate solubilizer) in multi-cut fodder oat improved the vegetative growth (Jayanthi et al., 2002). Kumar and Shivdhar (2006) at Jhansi observed that application of 50 per cent recommended dose of NPK, vermicompost 5 t/ha and FYM 5 t/ha may be adopted for getting higher, sustainable and quality fodder from single cut oat under irrigated conditions. Khanday et al. (2009) at Kashmir revealed that yield attributes viz., panicle length, grains/panicle, 1000-grain weight improved with the application of FYM, phosphorus and zinc up to 15 t/ha, 40 kg P₂O₅/ha and 10 kg Zn, respectively. Rawat and Agrawal (2010) at Jabalpur, M. P. revealed that application of vermicompost 5 t/ha along with inoculation of azotobacter @ 2 kg/ha enhanced the fodder, dry matter and protein yields and maximum yield of 360.1, 93.4 and 7.40 q/ha, respectively, and the same treatment also gave 3.76 q/day fodder supply with net profit of Rs. 14199.8/ha. Similarly, Patel et al. (2010) at Anand, Gujarat and Devi et al. (2014) at Hisar found that azotobacter inoculation increased plant height, tillers per metre row, leaf : stem ratio and produced significantly higher green forage, dry matter and crude protein yields resulting in higher realization as compared to without biofertilizer inoculation. Deva et al. (2014) also found that highest green fodder and dry fodder yields and net returns and B : C ratio were recorded in the plots treated with 100 per cent RDF+Bio-fertilizers (Azotobacter+PSB). Ahmad et al. (2011) found significant results in respect of plant height (146.3 cm), number of leaves per plant (6.87), number of tillers per plant (8.02), number of tillers/m² (336), leaf area per plant (128 cm²), fresh weight per tiller (30.10 g), dry weight per tiller (5.01 g) and green fodder yield (74.67 t/ha) in 100 per cent NPK inorganic fertilizers in contrast to organic manure. Godara et al. (2012) reported that higher green herbage, dry matter yield and quality of oat could be obtained with integration of either vermicompost @ 5 t/ha or FYM @ 10 t/ha and Azotobacter with 75 per cent of recommended dose of fertilizer (100% RDF–Nₘₙₚₚₙₚₖₙₚₚₖₚ₉ₚₕₚ₆ₙₚₖₚ₉ₕₚ₆ₙ) resulted in saving of 25 per cent chemical fertilizers. Rana et al. (2013) at Hisar found that foliar application of 0.5 per cent ZnSO₄ at 35 and 45 DAS+RDF recorded maximum green fodder yield of 593.3 and 488.3 q/ha as well as dry matter yield of 171.6 and 141.6 q/ha during 2009 and 2010, respectively. Verma et al. (2016) conducted an experiment at Navsari and concluded that FYM application @ 10 t/ha significantly increased seed yield (49.97 q/ha), straw yield (106.60 q/ha), N (81.63 kg/ha), P (23.65 kg/ha) and K (42.91 kg/ha) uptake by seed and N (129.35 kg/ha), P (26.40 kg/ha) and K (102.98 kg/ha) uptake by straw over control.

Barley

Barley is a dual purpose cereal, which can permit forage production in early season in addition to the grain yield later on (Singh et al., 2012b). Ram and Dhaliwal (2012) at Punjab Agricultural University, Ludhiana recorded the highest productivity under 75
per cent RDF+FYM and in 75 per cent RDF+FYM+biofertilizer. These manures along with RDF also helped in increasing the DTPA-extractable Zn, Cu, Fe and Mn in the soil. The highest gross returns, net returns and B : C ratio were recorded in 75 per cent RDF+FYM and in 75 per cent RDF+FYM+biofertilizer. It might be due to higher grain yield and lower variable costs recorded in these treatments. Singh and Chauhan (2016) at Bichpuri, Agra recorded maximum values of number of effective shoots/m, spike length (cm), number of spikelets/spike, number of fertile spikelets/spike, number of grains/spike, weight of grains/spike (g), 1000-grain weight (g), grain yield and straw yield were recorded at 75 per cent NPK+5 t FYM/ha+biofertilizer over lower levels of NPK and control. Singh et al. (2016) at Hisar revealed that highest green fodder yield of dual purpose barley was obtained with nitrogen application in two splits (2/3 at basal+1/3 immediate after cut) which was significantly superior to all other treatments except T3 (1/2 at basal+1/4 immediate after cut+1/4 at next irrigation).

**Cowpea**

Cowpea (*Vigna unguiculata*), being leguminous crop, requires only starter dose of nitrogen (15-25 kg N/ha) and balance requirement (50-90%) is met through symbiotic nitrogen fixation. A positive interaction between the different forms of nutrient carriers entails the exploitation of potentials through INM for legume-based cropping systems. Combination of organic and inorganic nutrient sources gave significantly better results than when either was used alone with regard to the growth of cowpea plants (Subbarayappa et al., 2009; Menon et al., 2010; Patil et al., 2012). Application of organic manure increased the yield significantly over no manure application and biofertilizer and organic spray helped increasing the dry matter production, over no biofertilizer application (Abraham and Lal, 2002). Shekara et al. (2010) reported that application of 80 kg P2O5/ha recorded higher green fodder (572.2 q/ha), dry matter (101.4 q/ha), crude protein yield (14.1 q/ha) and net monetary returns (Rs. 27115/ha). Das et al. (2011) at Akola reported that plant height, number of leaves and branches per plant, number of pods, diameter and length of pods were significantly increased to a greater extent by the treatment 75 per cent RDF+Vermicompost+Rhizobium+PSB as compared to RDF alone and it saved 25 per cent chemical fertilizer. Senthilkumar and Sivagurunathan (2012) observed higher number of pods in cowpea by combined inoculation of *Rhizobium*, *Phosphobacteria* and *Azospirillum*. Kumar and Pandita (2016) at Karnal also reported that integrated use of inorganic fertilizers+vermicompost 2.5 t/ha (4.76 and 4.16 q/ha) performed significantly better than the control (3.32 and 2.79 q/ha) for seed yield and its attributes as well as seed quality parameters during kharif 2012 and 2013, respectively. It was at par with combined use of inorganic fertilizers+biofertilizer inoculation (*Rhizobium*+PSB)+VAM 10 kg/ha also; the mean cost : benefit ratios (2.04 and 1.90) were highest for combination of biofertilizer inoculation (*Rhizobium*+PSB)+VAM 10 kg/ha+inorganic fertilizers 100 and 75 per cent RDF, respectively.

**Berseem**

Berseem is one of the most important fodder crops of rabi season and has been rightly described as the king of fodders. Berseem responded better to integrated nutrient management practices in terms of both forage and seed yields. Application of 20 kg N+60 kg P+ mixture of *Rhizobium trifolii* and phosphate solubilizing bacteria (PSB) recorded highest green fodder (65.45 t/ha), dry matter yield (16.98 t/ha) and protein content (19.7%) of berseem (Meena and Mann, 2006). Application of 50 per cent recommended NPK dose+2 t poultry manure/ha recorded the maximum plant growth, height and number of branches/plant, highest green forage yield in all the cuts and total of all the cuts in berseem followed by 100 per cent recommended NPK dose (Mishra and Mukherjee, 2002). Bali et al. (2007) underlined that application of 100 per cent NPK with 10 t FYM/ha to rice-berseem system increased the grain and straw yield of rice as well as green fodder yield of succeeding berseem at Shalimar, Srinagar, and Jammu & Kashmir. Basanthi et al. (2012b) reported that application of farm yard manure+*Rhizobium*+phosphate solubilizing bacteria+*Azospirillum* resulted in maximum plant height (13.1 cm at 35 DAS), fresh forage yield (16780 kg/ha), maximum length of head (2.7 cm), maximum number of flowers per head (83 flowers/ head) and maximum seed yield (387.2 kg/ha). Pal (2015) reported that application of 10 t/ha FYM along with sulphur, boron and molybdenum had higher plant height, leaf : shoot ratio, green and dry forage yield and also crude protein production of berseem than application of both treatments either 100 per cent RDF (inorganic source)
or RDF+FYM @ 5 t/ha +S+Mo+B and recommended that the berseem should be fertilized with 10 t/ha FYM+30 kg sulphur+4 kg boron+1 kg molybdenum/ha in place of chemical fertilizer for higher productivity and quality of berseem herbage.

CONCLUSION

INM not only optimized the chemical fertilizer application (consequently reducing the environmental pollutions), but it also enhanced forage quality in terms of higher macro and micronutrient concentrations. Combined application of inorganic fertilizers with different sources of organic manures in different proportions has significant role to boost forage productivity, improve nutrient uptake by plants and maintain soil nutrient status. Higher maize and pearl millet yield recorded with application of 50 per cent N through FYM and 50 per cent NPK through inorganic fertilizers. Application of sulphur (40 kg/ha), Zn (20 kg/ha) and Mn (10 kg/ha) along with recommended NPK to sorghum gave significantly higher dry fodder yield by 16.5 per cent over NPK alone. Higher green herbage, dry matter yield and quality of oat can be obtained with integration of either vermincompost @ 5 t/ha or FYM @ 10 t/ha and Azotobacter with 75 per cent of recommended dose of fertilizer resulted in saving of 25 per cent chemical fertilizer. Maximum grain and straw yield of barley was recorded at 75 per cent NPK+5 t FYM/ha+biofertilizer over lower levels of NPK and control. Combination of organic and inorganic nutrient sources gave significantly better results than when either were used alone with regard to the growth of cowpea plants. Berseem should be fertilized with 10 t/ha FYM+30 kg sulphur+4 kg boron+1 kg molybdenum/ha in place of chemical fertilizer for higher productivity and quality of berseem herbage.

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