Forage Res., **43** (1) : pp. 9-16 (2017) **http://forageresearch.in**

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

MUKESH KUMAR*, BHAGAT SINGH AND A. K. DHAKA

Department of Agronomy
CCS Haryana Agricultural University,
Hisar-125 004 (Haryana), India
(e-mail : mukeshkumarkainwal@gmail.com)

(Received : 4 February 2017; Accepted : 7 March 2017)

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 bio-fertilizers (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 bio-fertilizers 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 P_2O_5+33.2 kg K_2O 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 through urea fertilizer 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 to77.48, 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+P_2O_5 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 farm yard 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 $ZnSO_4$/ha as basal or 10 kg $ZnSO_4$ 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/ha) 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 Shivadhar (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 P_2O_5/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/m^2 (336), leaf area per plant (128 cm^2), 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–$N_{80}P_{40}$) resulted in saving of 25 per cent chemical fertilizers. Rana *et al*. (2013) at Hisar found that foliar application of 0.5 per cent $ZnSO_4$ 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 T_2 (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 P_2O_5/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+ *Azospirillium* 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+bio-fertilizer 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.

REFERENCES

Abraham, T., and R. B. Lal. 2002 : Sustainable enhancement of yield potential of fodder cowpea (*Vigna unguiculata)* through integrated nutrient management (INM) in a legume-based cropping system for the inceptisols. *Forage Res.,* **28** : 147- 152.

Afzal, A., A. Ahmad, and A. H. Ahmad. 2013 : Impact of nutritional sources of nitrogen and phosphorus fertilizers on growth, yield and quality of forage oat. *Cercetari Agronomice in Moldova*. **45** : 57-64.

Ahmad, A. H., A. Wahid, F. Khalid, N. Fiaz, and M. S. Zamir. 2011 : Impact of organic and inorganic sources of nitrogen and phosphorus fertilizers on growth, yield and quality of forage oat (*Avena sativa* L.). *Cercetari Agronomice în Moldova.* **3** : 147.

Ahmad, W., Z. Shah, F. Khan, S. Ali, and W. Malik. 2013 : Maize yield and soil properties as influenced by integrated use of organic, inorganic and bio-fertilizers in a low fertility soil. *Soil Environ.*, **32** : 121-129.

Ali, K., S. K. Khali, F. M. Abdurrab, K. Nawab, A. Z. Khan, A. Kamal, and Z. H. Khan. 2012 : Response of maize to various nitrogen sources and tillage practices. *Sarhad J. Agric.,* **28** : 9-14.

Antil, R. S. 2012 : In : *Integrated Plant Nutrient Supply for Sustainable Soil Health and Crop Productivity,* A. Kumar (ed.) *Vol. 3.* Focus Global Reporter.

Anonymous. 2011 : *IGFRI Vision 2030.* Indian Grassland and Fodder Research Institute, Jhansi (U. P.), India.

Bali, A. S., D. Kachroo, and A. K. Bhat. 2007 : Studies on integrated nutrient management of rice in rice-berseem cropping system under temperate agro-climatic conditions of Jammu & Kashmir. *J. Res*., **6** : 73-78.

Basanthi, C., S. C. Biyan, P. Dhuppar, and D. S. Rao. 2012a : Integrated nutrient management impact on performance of hybrid and composite cultivars of pearl millet (*Pennisetum glaucum*). *Forage Res.,* **38** : 102-105.

Basanthi, C., S. C. Biyan, P. Dhuppar, and D. S. Rao. 2012b : Studies on the potential of integrated nutrient management for improving the vegetative and reproductive performance of berseem crop. *Forage Res.,* **37** : 248-250.

Chakraborti, M., and N. P. Singh. 2004 : Bio-compost : A novel input to organic farming. *Agrobios Newsletter*, **2** : 14-19.

Cheema, M. A., W. Farhad, M. F. Saleem, H. Z. Khan, A. Munir, M. A. Wahid, F. Rasul, and H. M. Hammad. 2010 : Nitrogen management strategies for sustainable maize production. *Crop Environ.*,**1** : 49-52.

Choudhary, R. S., and R. C. Gautam. 2007 : Effect of nutrient-management practices on growth and yield of pearl millet (*Pennisetum glaucum*). *Indian J. Agron.,* **52** : 64-66.

Das, A., N. K. Lenka, S. Sudhishri, and U. S. Patnaik. 2008 : Influence of integrated nutrient management on production, economics and soil properties in tomato (*Lycopersicon esculentum*) under on-farm condition in Eastern Ghats of Orissa. *Indian J Agric. Sci.,* **78** : 40-43.

Das, B., A. P. Wagh, V. N. Dod, P. K. Nagre, and S. O. Bawkar. 2011 : Effect of integrated nutrient management on cowpea. *Asian J. Hort.,* **6** : 402-405.

Dasog, V. G. S., H. B. Babalad, N. S. Hebsur, S. K. Gali, S. G. Patil, and A. R. Alagawadi. 2012 : Nutrient status of soil under different nutrient and crop management practices. *Karnataka J. Agric. Sci.,*

25 : 193-198.

Deva, S., A. Tandon, and P. Pandey. 2014 : Effect of tillage practices and nutrient management on yield and economics of fodder oat. *Forage Res.*, **40** : 49-50.

Devi, U., K. P. Singh, S. Kumar, and M. Sehwag. 2014 : Effect of nitrogen levels, organic manures and azotobacter inoculation on yield and economics of multi-cut oats. *Forage Res.*, **40** : 36-43.

Duhan, B. S. 2013 : Effect of integrated nutrient management on yield and nutrients uptake by sorghum (*Sorghum bicolor* L.). *Forage Res.*, **39** : 156-158.

Dutta, J., N. K. Sankhyan, S. P. Sharma, and S. K. Sharma. 2013 : Long-term effect of chemical fertilizers and soil amendments on sustainable productivity and sulphur nutrition of crops under maize-wheat cropping system in an acid alfisol. *J. Acad. Indust. Res.*, **2** : 412-416.

Ghaffari, A., A. Ali, M. Tahir, M. Waseem, M. Ayub, A. Iqbal, and A. U. Mohsin. 2011 : Influence of integrated nutrients on growth, yield and quality of maize (*Zea mays* L.). *Am. J. Plant Sci.*, **2** : 63-69.

Godara, A. S., U. S. Gupta, and R. Singh. 2012 : Effect of integrated nutrient management on herbage, dry fodder yield and quality of oat (*Avena sativa* L.). *Forage Res.*, **38** : 59-61.

Golada, S. L., B. J. Patel, P. Singh, and L. R. Buldak. 2010 : Effect of integrated nutrient management on productivity of forage pearl millet (*Pennisetum glaucum* L.). *Forage Res.*, **36** : 185-187.

Hossain, N., M. G. Kibria, and K. T. Osman. 2012 : Effects of poultry manure, household waste compost and inorganic fertilizers on growth and yield of maize (*Zea mays* L.). *IOSR J. Pharm. Biol. Sci.*, **3** : 38-43.

Jayanthi, C., P. M. Khan, A. K. Fazullah, and C. Chinnusamy. 2002 : Integrated nutrient management in forage oat (*Avena sativa*). *Indian J. Agron.*, **47** : 130-133.

Kalhapure, A. H., and M. B. Dhonde. 2013 : Integrated nutrient management in maize (*Zea mays* L.) for increasing production with sustainability. *Int. J. Agric. Food Sci. Technol.*, **4** : 195-206.

Kannan, R. L., M. Dhivya, D. Abinaya, R. L. Krishna, and S. K. Kumar. 2013 : Effect of integrated nutrient management on soil fertility and productivity in maize. *Bull. Env. Pharmacol. Life Sci.*, **2** : 61-67.

Karki, T. B., A. Kumar, and R. C. Gautam. 2005 : Influence of integrated nutrient management on growth, yield, content and uptake of nutrients and soil fertility status in maize (*Zea mays*) in New Delhi. *Indian J. Agric. Sci.*, **75** : 682-685.

Kemal, Y. S., and Abera, M. 2015 : Contribution of integrated nutrient management practices for sustainable crop productivity, nutrient uptake and soil nutrient status in maize based cropping systems. *J. Nutr.*, **2** : 1-10.

Khanday, B. A., A. R. Samoon, W. Raja, J. Khanday, and F. A. Bahar. 2009 : Integrated nutrient management for seed production of oat (*Avena sativa* L.) under temperate conditions of Kashmir. *Int. J. Agric. Sci.*, **5** : 145-147.

Kumar, A., H. P. Yadav, and D. Vart. 2012a : Sustaining productivity of high yielding hybrids of pearl millet through zinc. *Forage Res.*, **38** : 23-26.

Kumar, A., P. Kumar, S. K. Yadav, and R. C. Hasija. 2012b. Effect of integrated nutrient management on yield and economics of pearl millet-wheat cropping system. *Environ. Ecol.*, **30** : 57-59.

Kumar, A., R. C. Gautam, R. Singh, and K. S. Rana. 2005 : Growth, yield and economics of maize-wheat cropping sequence as influenced by integrated nutrient management of New Delhi. *Indian J. Agric. Sci.*, **75** : 709-711.

Kumar, A., and V. K. Pandita. 2016 : Effect of integrated nutrient management on seed yield and quality in cowpea. *Legume Res.*, **39** : 448-452.

Kumar, P., R. Singh, A. Singh, D. Paliwal, and S. Kumar. 2014 : Integrated nutrient management in pearl millet (*Pennisetum glaucum*)-wheat (*Triticum aestivum*) cropping sequence in semi-arid condition of India. *Indian J. Agric. Sci.*, **10** : 96-101.

Kumar, S., and Shivadhar. 2006 : Influence of organic and inorganic sources of nutrients on forage productivity and economics of oat (*Avena sativa* L.). *Ann. Agric. Res.*, **27** : 205-209.

Meena, L. R., and J. S. Mann. 2006 : Strategic nutrient supplementation in berseem for higher biomass productivity and economic returns under semi-arid conditions. *Range Manage. Agrof.*, **27** : 40-43.

Menon, M. V., D. B. Reddy, P. Prameela, and J. Krishnankutty. 2010 : Seed production in vegetable cowpea [*Vigna unguiculata* (L.) Walp.] under integrated nutrient management. *Legume Res.*, **33** : 299-301.

Mishra, G. C., and A. K Mukherjee. 2002 : Effect of NPK doses with and without poultry manure and levels of sulphur on growth and herbage yield of Egyptian clover. *Forage Res.*, **28** : 98-103.

Pal, M. S. 2015 : Effect of macro- and micro-nutrients on herbage yield and quality of berseem (*Trifolium alexandrinum* L.) in *tarai* region of Indo-Ganagetic plains. *Indian J. Plant Soil*, **2** : 77-80.

Palaniappan, S. P., and K. Annadurai. 2007 : *Organic Farming : Theory and Practices*. Scientific Publishers, Jodhpur, India. pp. 169.

Patel, M. R., T. G. Meisheri, and A. C. Sadhu. 2010 : Effect of irrigation, nitrogen and bio-fertilizer on faorage yield and quality of oat (*Avena sativa* L.). *Forage Res.*, **35** : 231-235.

Patil, S. D., D. J. Dabke, M. C. Kasture, N. G. Chavan, and V. J. Palsande. 2012 : Effect of N, K and biofertilizers on yield and quality of cowpea (*Vigna unguiculata* L.) in Konkan region. *Bioinfolet.*, **9** : 468-469.

Puri, K. P., and U. S. Tiwana. 2008 : Effect of organic and inorganic sources of nitrogen in forage maize. *Forage Res.*, **34** : 62-63.

Quanshah, G. W. 2010 : Effect of organic and inorganic fertilizers and their combinations on the growth and yield of maize in the semi-deciduous forest zone of Ghana. M. Sc. thesis, Department of Crop and Soil Sciences, College of Agriculture and Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

Ram, H., and S. S. Dhaliwal. 2012 : Effect of varieties and integrated nutrient management techniques on growth, productivity, quality and economics of barley (*Hordeum vulgare* L.). *Indian J. Agric. Sci.*, **8** : 91-97.

Rana, D. S., B. Singh, K. Gupta, A. K. Dhaka, and S. Arya. 2013 : Response of fodder sorghum (*Sorghum bicolor* L.) to zinc and iron. *Forage Res*., **39** : 45-47.

Rasool, S., R. H. Kanth, S. Hamid, W. Raja, B. A. Ali, and Z. A. Dar. 2015 : Influence of integrated nutrient management on growth and yield of sweet corn [*Zea mays* (L.) *saccharata*] under temperate conditions of Kashmir Valley. *Am. J. Exp. Agric.*, **7** : 315-325.

Rawat, A., and S. B. Agrawal. (2010) : Effect of soil enrichment in conjunction with bio-organics and chemical fertilizers on yield and quality of fodder oat (*Avena sativa* L.). *Forage Res*., **35** : 190-192.

Sarwar, M., J. Ghulam, R. Ejaz, A. M. Ehsan, and C. A. Nawaz. 2012 : Impact of integrated nutrient management on yield and nutrient uptake by maize under rainfed conditions. *Pak. J. Nutr.*, **11** : 27-33.

Sathish, A., V. G. Gowda, H. Chandrappa, and K. Nagaraja. 2011 : Long term effect of integrated use of organic and inorganic fertilizers on productivity, soil fertility and uptake of nutrients in rice and maize cropping system. *Int. J. Soil Nutr.*, **2** : 84-88.

Senthilkumar, P. K., and P. Sivagurunathan. 2012 : Comparative effect on bacterial biofertilizers on growth and yield of greengram (*Phaseolus radiata* L.) and cow pea (*Vigna sinensis* Edhl.). *Int. J. Curr. Microbiol. App. Sci*., **1** : 34-39.

Sharma, A., H. Singh, and R. K. Nanwal. 2007 : Effect of integrated nutrient management on productivity of wheat (*Triticum aestivum*) under limited and adequate irrigation supplies. *Indian J. Agron.*, **52** : 120-123.

Sharma, S. K., and S. R. Bhunia. 2001 : Response of oat (*Avena sativa*) to cutting management, method of sowing and nitrogen. *Indian J. Agron*., **46** : 563-567.

Shekara, B. G., H. C. Lohithaswa, M. Govindappa, and R. Pavan. 2010 : Response of fodder cowpea genotypes to varied levels of phosphorus. *Forage Res.*, **36** : 91-93.

Singh, B., A. K. Dhaka, and M. Kumar. 2016. Performance of dual purpose barley varieties under different nitrogen application schedules. *Forage Res*., **41** : 246-248.

Singh, B., D. S. Rana, U. N. Joshi, and A. K. Dhaka. 2012a : Fodder yield and quality of pearl millet genotypes as influenced by nitrogen levels. *Forage Res.*, **38** : 62-63.

Singh, D., D. R. Singh, V. Nepalia, and A. Kumari. 2012b : Performance of dual purpose barley (*Hordeum vulgare* L.) varieties for green fodder and subsequent productivity under varying seed rates and fertility management. *Forage Res.*, **38** : 133-137.

Singh, K., Joshi, Y. P., and H. Chandra. 2015 : Effect of integrated nutrient management on growth, productivity and quality of sweet sorghum (*Sorghum bicolor*). *Indian J. Agron.*, **60** : 291-296.

Singh, S. B., and S. K. Chauhan. 2016 : Effect of integrated nutrient management on barley (*Hordeum vulgare* L.) under semi-arid conditions of western Uttar Pradesh. *Technofame*, **5** : 20-23.

Subbarayappa, C. T., S. C. Santhosh, N. Srinivasa, and V. Ramakrishnaparama. 2009 : Effect of integrated nutrient management on nutrient uptake and yield of cowpea in southern dry zone soils of Karnataka. *Mysore J. Agric. Sci.*, **43** : 700-704.

Swarup, A. 1998 : Emerging soil fertility management issues for sustainable crop productivity in irrigated systems. In : *Long Term Soil Fertility Management through Integrated Plant Nutrient Supply*, Swamp, A., Damodar, Reddy, and R. N. Prasad (eds.). Indian Institute of Soil Science, Bhopal, Madhya Pradesh, India. pp. 54-67.

Tiwana, U. S., and D. P. Chaudhary. 2009 : Effect of integrated nutrient management on the yield and quality of forage sorghum. *Forage Res*., **35** : 56-58.

Tripathi, S. B., M. R. Pahwa, R. K. Bhatt, and M. S. Sharma. 2007 : *Annual Report*. IGFRI, Jhansi, India.

Verma, C., J. D. Thanki, D. Singh, and S. N. Chaudhari. 2016 : Effect of nitrogen, bio-fertilizer and fertilizer and farm yard manure on yield and nutrient uptake in oat (*Avena sativa* L.). *The Bioscan*., **11** : 499-501.

Yadav, A. K., P. Singh, and K. Singh. 2012 : Growth, yield and economics of sorghum (*Sorghum bicolor* L.) affected by tillage and integrated nutrient management. *Forage Res*., **38** : 40-43.

Yadav, P. C., A. C. Sadhu, and P. K. Swarnkar. 2007 : Yield and quality of forage sorghum (*Sorghum sudanense*) as influenced by the integrated N management. *Indian J. Agron*., **52** : 330- 334.

Yadav, P. C., A. C. Sadhu, P. K. Swarnakar, and Patel, M. R. 2010 : Effect of integrated nitrogen management on forage yield of multicut sorghum, available nitrogen and microbial count in the soil. *J. Indian Soc. Soil Sci.*, **58** : 303-308.