Review Article

Role of integrated nutrient management on oat: A review

Abstract

Food security and environmental safety are the two important areas receiving major setback with the use of chemical fertilizers. Food supply in a sustainable manner in response to population demand urges for a paradigm shift of chemical based agriculture to some eco-friendly approaches. Integrated nutrient management or combined approach of using different sources of nutrients is relevant in this context as it optimises profitable crop production and improves soil health without deteriorating environment further. Food supply not only comes from agriculture but also from livestock sector. Therefore, cultivation of dual purpose (food and fodder) crop like oat is gaining importance day by day. Adequate nutrition to oat directly reflects on livestock and human nutrition. Researches around the globe indicate that integrated nutrient management in oat is now gaining momentum as it holds good promise as a successful replacement of sole chemical fertilizer. However, poor transfusion and lack of policies make this technology to remain as a dormant. Therefore, further research works regarding integrated nutrient management on oat and its true transfusion to farming community are the needs of the hour to protect livestock and human food security and to free the environment from clutches of chemical hazards in coming days.

Comment [A1]: chemical-based

Key words: Environment safety, Food security, Integrated nutrient management, Livestock productivity, Oat

1. Introduction

Livestock is a major contributor of a nation's economy and it plays a crucial role in food supply (milk, eggs and meats) to burgeoning population. Besides, livestock provides various non-food items as raw materials in textile, leather and cosmetic industries as well as manure for agricultural productivity. In rural areas of developing countries like India, livestock still plays a pivotal role in various agricultural operations (ploughing, weeding and inter culture, post-harvest threshing and processing), transportation and carrying goods. Livestock sector holds good prospects for generation of income, employment opportunities and maintenance of social status and wellbeing of communities (Moyo and

Swanepoel, 2010). India tops the chart with 535.78 million livestock population and generates 16% income, 8.8% employments and contributes 4.11% and 25.6% in GDP and agricultural GDP, respectively (Govt. of India, 2019). However, as compared to other countries, livestock productivity in India is comparatively low due to malnutrition, lack of feeding and poor livestock genetic potential. Livestock productivity and fodder production as well as supply of nutrition are very much linked to each other (Karki, 1985). However, over the years, cultivation of fodder crops has received negligence and attention is mostly paid towards cultivation of food and commercial crops (Biswas *et al*., 2019a). Presently, in India, acute shortages of green fodder, dry straw and concentrates by 35.60%, 10.95% and 44%, respectively, clearly portrait disparity between demand and supply of livestock produce (IGFRI, 2013). Besides, fodder supply with inadequate nutritional quality is another obstacle towards realising optimum livestock potential (Roy, 1993). Under consistent shrinkage of agricultural land by population growth and habitation, expansion of fodder cultivation sacrificing major food crops right now or in near future is difficult and therefore, urges for diversification of cropping system and inclusion of dual purpose crops (food and fodder) like oat (*Avena* spp.) which is a promising winter growing cereal as it provides not only nutritious fodder to animals but also food grains for human consumption (Jena *et al*., 2018). It ranks 6th in terms of production just after wheat, rice, maize, sorghum and barley (Puneeth Raj and Vyakaranahal, 2014) and can be fed to milch and drought animals in any form viz. green and dry fodders, silage, hay as it is nutritionally rich in protein, iron, phosphorus, vitamin B (Tiwana *et al*., 2008), carbohydrate, zinc, manganese, soluble fiber (Kashyap *et al*., 2017) etc.

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As oat is highly responsive to nutrients, performance of oat in terms of quantitative and qualitative production to a large extent depends on adequate nutrition which imparts consequent effects on animal and human nutrition. Optimization of nutrient application in this crop is most important to relish its outcome. So far, researchers from various parts of the world have developed several interventions of oat crop nutrition and researches are still on going. One such promising intervention is integrated nutrient management (INM). Keeping all these facts in mind, this article has been shaped to best highlight the salient findings of researchers who have cultivated oat by using INM.

2. Integrated nutrient management (INM)

Green revolution at beginning showed good promise which gradually decreased along with decrease of partial factor productivity and nutrient use efficiency (Jena *et al*., 2018) along with deterioration of soil health, ground water contamination, atmospheric pollution and climate change under unscientific use of inorganic fertilizers (Aulakh *et al.*, 2009). Although organic manure supplies all the essential nutrients and improves soil health without deteriorating environment, it is not possible to obtain high agricultural productivity through its application alone. Therefore, both organic and inorganic sources of nutrients should be integrated in a balanced form to utilize benefits and curtail down limitations of both. INM improves soil health and fertility, secures environment and sustains agricultural productivity in a holistic way (Mahajan and Gupta, 2009). Chemical fertilizers, organic manures such as FYM, vermicompost, green manure, poultry manure, sheep manure etc., biofertilizers such as *Azotobacter*, *Trichoderma*, *PSB* etc. are the principal components of INM. For instances, poultry manure is a rich source of nutrients and act as soil amendment for improvement of soil health. Use of poultry or chicken manure in INM improves nutrient availability and uptake by plants. FYM increases the soil fertility status, physical and biological health of soil and improves water holding capacity. Besides, availability of various kinds of essential nutrients in FYM, which is devoid in primary chemical fertilizers, enhances uptake of nutrients and growth of the plants. Vermicompost shows positive impacts on better root system, easy mineralization, availability and uptake of nutrients resulting in good plant vigour. Vermicompost enhances soil microbial activities. Besides, it contains plant growth promoters. Application of vermicompost as a part of INM improves nutrient mobilization and availability for plant uptake resulting in increment of plant growth. Micronutrients such as zinc, sulphur etc. play important role as they are important constituents of some essential enzymes and proteins in plant development process. Biofertilizer is another important part of INM (Sahoo *et al*., 2014). In an eco-friendly way, it enhances microbial dynamics in soil and helps in solubilisation, nitrogen fixation (Sharma and Verma, 2004) nutrient mobilization at faster rate (Sinha *et al*., 2014). However, in order to achieve sustainable and profitable crop production with INM, standardization of integration of various sources of nutrients is the most important requisite.

Comment [A8]: Use newer references (2015-2022)

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Comment [A10]: Refer to the results of the researchers' experiments

3. Integrated nutrient management in oat

In the contexts of soil fertility and oat productivity with chemical fertilizer, INM plays an important role in enhancing soil physical, chemical and biological health and thereby, positively influence oat cultivation. Unfortunately, use of INM in oat cultivation is very much limited due to lack of research works, awareness and technology transfusion. However, few research works clearly depict INM as promising technology for improving soil fertility, growth, yield, quality and profitability of oat cultivation.

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Add research results from others

3.1.Growth attributes of oat

Influence of growth attributes as an indicator of oat performance has been documented by various researchers over the years in their studies incorporating integrated nutrient management (INM). Positive results from their works certainly confirm that growth attributes of oat significantly vary according to various INM options implemented (Table 1).

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3.2.Yield attributes and yield of oat

Yield is a reflection of plant growth specially, in case of fodder crops like oat. Healthy growth of plant undergoes high photosynthetic and partitioning activities which enhances the yield. INM improving the plant growth of oat consequently imparts positive influence on oat fodder and grain yields. Organic manures such as FYM, vermicompost, poultry or sheep manures etc. can improve plant growth such as high leaf area to undergo photosynthetic activities of plant and translocation of assimilates from source to sink. Beside the organic manures and micronutrients, reports are available regarding the beneficial role of biofertilizers in oat yield enhancement. However, Tiwana and Puri (2004) did not found any influence of seed inoculation through *Azotobacter* on seed yield of oat indicating the dependence of biofertilizers on soil and agro-climatic condition. Integrated nutrient management not only plays an important role in improving the production of the crop in which it is applied, but also enhances the performance of succeeding crop through improvement of residual soil fertility. Raja *et al*. (2019) reported that residual soil fertility after cultivation of sorghum with application of 120:60:30 kg $N:P_2O_5:K_2O$/ha along with 25 t FYM/ha was able to ensure high quantities of dry matter and green fodder yields of succeeding crop oat. Earlier, Barik *et al.* (2005) also obtained good amount of green fodder of oat grown on residual soil fertility after cultivation of *kharif* rice using integrated nutrient management. Roy *et al.* (2009) similarly noticed sizeable quantities of green and dry fodder yield of oat grown under residual soil fertility after *kharif* rice grown with the use of 50% RDF along with FYM @ 10t/ha. Not only integration of various sources of nutrients, but also the combination of different nutrient management options exerts influence on oat. Shikha and Singh (2018) noticed that green forage yield and dry matter yield of oat were significantly increased through implementation of soil test crop response (STCR) and integrated nutrient management (INM) due to improvement of soil fertility status. Research findings indicating influence of INM on yield attributes and yield of oat have been mentioned in Table 2.

Comment [A13]: Replace old references with newer references

3.3. Quality of oat

Quality of oat either as fodder or grain is the one of the important factors in deciding the success of its cultivation as it imparts direct impact on livestock and human nutrition. INM incorporating organic manures or biofertilizers releases the nutrients like nitrogen efficiently which has positive role in quality enhancement of the produce. Several works relating INM options exhibiting positive influence on quality parameters of oat have been listed in Table 3.

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Match with test results of others

3.4.Soil and plant nutrient status

Integrated nutrient management plays a crucial role in improving soil fertility status which can curtail down the use of environmentally harmful and costly fertilizers for the present and next crops (Yadav *et al*., 2018). Improvement of soil fertility through INM also consequently improves nutrient uptakes and concentrations inside the plants. Over the years, researchers have studied the variable response of INM involving organic manures, biofertilizers, micronutrients etc. on soil fertility and plant nutrient status of oat cultivation. Results were mostly positive suggesting the future prospects of INM in the present context of soil health deterioration (Table 4). Devi *et al*. (2015) indicated high residual soil fertility status after oat cultivation using organic, inorganic nitrogen and seed inoculant (*Azotobacter*) as combination to exert positive influence on growth and yield of succeeding crop sorghum. Roy *et al.* (2009) noticed high nutrient uptakes of oat grown under residual soil fertility after *kharif* rice grown with the use of 50% RDF along with FYM @ 10t/ha. Singh *et al*. (2019) also documented the effectiveness of INM in oat in increment of soil nutrient status which sustained the production of succeeding crop maize. Beside different sources of nutrients, integration of nutrient management methods exerting influence on oat's nutrient uptakes was reported by Shikha and Singh (2018) as they observed combined use of STCR and INM improved N, P and K uptake of oat over use of general recommended doses of fertilizers.

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3.5.Nutrient use efficiency and soil biological health

Betterment of nutrient use efficiency is a major objective for sustainable crop production. Besides, improvement of soil biological health (microbial and enzymatic activities) is another important factor for enhancement of soil productivity. It has been reported by various scientists around the world that INM significantly impacts on nutrient use efficiency and biological health of soil. Success of oat cultivation under INM not only relies on crop performance, but also on improvement of nutrient use or utilization efficiency and biological properties of soil. Khan *et al.* (2019) observed that nutrient use efficiencies such as partial factor productivity (PFP), agronomic nitrogen use efficiency (ANUE), apparent nitrogen recovery efficiency (ANRE) of naked oat (*Avena nuda* L.) were significantly higher under application of 50% N through chemical source along with 50% N through organic and microbial fertilizer sources which was closely followed by application of 75% N through chemical source along with 25% N through organic and microbial fertilizer sources over control and 100% N through chemical source and however, physiological nitrogen use efficiency (PNUE) remained statistically indifferent irrespective of treatments. In their study, Khan *et al*. (2019) further noticed that among various INM options, application of 50% N through chemical source along with 50% N through organic and microbial fertilizer sources exhibited better soil respiration (CO_2) rate, enzymatic activities (acid phosphatase, dehydrogenase, arylsulphatase, BAA-protease, β-glucosidase) over control and 100% N through chemical source. Oat seed inoculation through biofertilizers has been also found to improve soil biological health. Deva (2015a) noticed increments of soil bacterial, fungal and actinomycetes populations with the application of 100% RDF along with oat seed inoculation through PSB and *Azotobacter*. Sheoran *et al.* (2000) obtained best nitrogen utilization efficiency in oat with the use of *Azotobacter* as seed inoculant along with application of 40 kg N/ha.

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3.6. Economics and energetics of oat cultivation

Improved crop production is not the sole factor in deciding the success of INM. Rather, it focuses on reduction of expenditure of crop cultivation for economically sound production. Since INM partly replaces the costly fertilizers with on farm organic sources of nutrients prepared from domestic and agricultural wastes, cost of production is within the bearable limit and thus, it is the promising approach for profitable crop production (Singh, 2017). Besides, in the present context of energy crisis, high energy expenditure in manufacturing chemical fertilizers is not affordable and in this respect, INM has a significant role in energy saving and conservation for future. Various researchers around the globe have already mentioned the economically and energetically profitable oat cultivation through INM in several literatures which suggest the paradigm shift from sole chemical fertilizer to INM. Khanday *et al*. (2009) reported better economic viability (net return and benefit-cost ratio) of oat cultivation in temperate climate of Kashmir from integrated application of 15 t FYM/ha, 40 kg phosphorus/ha and 10 kg zinc/ha due its effectiveness in enhancement of grain and straw yields. Sharma *et al*. (2004) achieved maximum economic viability of oat cultivation with the application of 50% RDF along with vermicompost and FYM each @ 2.5t/ha which was closely followed by application of 50% RDF along with vermicompost @ 2.5t/ha.Jena and Sarkar (2016) reported that application of *Azotobacter,* PSB, KSB and ZnSB along with 75% N, P, K and Zn resulted in lowest cost of cultivation and highest gross return, net return and return per rupee invested in oat which was followed by application of *Azotobacter,* PSB and KSB along with 75% N, P,K and recommended dose of Zn. Nanda *et al.* (1998) observed economically profitable oat production with the use of FYM along with 75% RDF. Devi *et al*. (2014) obtained higher gross and net returns from oat cultivation by application of 80 or 120 kg N/ha along with vermicompost @ 10t/ha and seed inoculation through *Azotobacter* over control, which was marginally followed by application of 80 or 120 kg N/ha along with FYM @ 10t/ha and seed inoculation through *Azotobacter*. Rawat and Agrawal (2010) also obtained high economic return from oat field with the use of 100% RDF along with vermicompost @ 5 t/ha and seed inoculation through biofertilizer (*Azotobacter*) @ 2kg/ha. Deva *et al*. (2014) reported that application of 100% RDF along with seed inoculation through PSB and *Azotobacter* recorded highest net realization and benefit-cost ration in oat cultivation. Patel *et al*. (2010) observed high net monetary return of oat cultivation with the application of 120 kg N/ha and seed inoculation through *Azotobacter*. Sharma and Verma (2005) obtained higher net return and return per rupee invested with the application of 150 kg N/ha along with seed inoculation through PSB and *Azotobacter* and energy ratio and energy productivity under the application of 100 kg N/ha along with seed inoculation through PSB and *Azotobacter*. Sharma (2009) found high economic viability, energy responsiveness, energy ratio and energy productivity of oat with the application of 100 kg N/ha along with *Azotobacter* seed inoculation and sheep manure @ 10 t/ha. Patel *et al.* (2002) recommended 40 kg N/ha along with seed inoculation through *Azotobacter* for economical oat seed production. Roy *et al.* (2009)

achieved economically sound oat cultivation under residual soil fertility after *kharif* rice grown with the use of 50% RDF along with FYM @ 10t/ha.

Comment [A17]: Replace old references with newer references

4. Conclusion

Results from several research on use of integrated nutrient management on oat as mentioned in this article are although very much variable due to reliance on agro-climatic, soil factors, varietal response and other management operations, one common thread connecting them is that oat performance is improved as and when INM is implemented. INM, to some extent, can be a suitable alternative of hazardous chemical fertilizer and can optimise the production, improve quality of crop, soil fertility and biological health and nutrient use efficiency in oat cultivation. Besides, it shows good prospects in returning economically and energetically sound produce to the farmers. However, limited availability of various organic sources of nutrients, lack of soil testing facilities, inappropriate methods and untimely use etc. are some issues associated with INM, which need to be addressed. Overuse of INM can also leave environmental consequences. Therefore, judicious use of this promising technology is most important. Research works regarding oat cultivation under INM is limited. Further, knowledge about potential of this technology is yet to reach to the farmers due to lack of awareness on consequences of chemical fertilizer use and poor extension services in transfusion of this technology. Since livestock productivity is very much connected with food security of today's population, oat cultivation with the objective to improve crop productivity is the area to focus on right now. Government and private organisations individually or in collaboration, must come forward to adopt INM and emphasize on oat productivity improvement in an eco-friendly way through subsidies, campaign, demonstration and extension activities. More research works on optimization of INM for oat cultivation respective of varieties, purposes, soil, agro-climatic conditions and other factors, and their proper dissemination to grass-root level are needed to tackle present challenges associated with quantitatively and nutritionally poor production, food insecurity and environmental risks, and to realise sustainable and environmentally safe production in coming days.

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Comment [A18]: Be updated

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Table 1: Growth attributes of oat as influenced by various INM options

Growth attributes influenced	INM options	References
Plant height	75% RDF + 5t FYM/ha + 20 kg S/ha	Pandey (2018)
	50% N through chemical source + 50% N through organic and microbial fertilizer sources	Khan *et al.* (2019)
	120 kg N/ha + vermicompost @ 10t/ha + seed inoculation through *Azotobacter*	Devi *et al.* (2009)
Plant height and leaf:stem	Application of green manure along with 25% nitrogen through FYM and 50% of RDF through inorganic sources Application of green manure along with 25% nitrogen through FYM and 50% of RDF through biofertilizer	Hembram and Kundu (2016)
Plant height, tiller number/plant, tiller number/m^2, number and area of leaves/plant and dry matter/tiller	FYM or poultry manure as substitute of certain part of RDF	Ahmad *et al.* (2011)
Plant height, tiller numbers, tiller fresh and dry weights and leaf area/plant	50% N through urea and 50% N through poultry manure	Iqbal *et al.* (2014)
Crop growth rate	50% inorganic and 50% organic (FYM) or 75% inorganic and 25% organic	Khan *et al.* (2013)

	(FYM) sources of nutrients	
Plant height, leaf:stem, shoots/metre and leaves/plant	50% RDF + vermicompost and FYM each @ 5t/ha	Kumar and Dhar (2006)
Plant height, shoots/metre row length	100% RDF + 5 t vermicompost/ha	Godara *et al*. (2012)
Plant height, leaf and tiller numbers	100% RDF + vermicompost @ 5t/ha/FYM @ 10 t/ha + $ZnSO_4$ @ 15 kg/ha	Puneeth Raj and Vyakaranahal (2014)
Plant height and tiller numbers	50% RDF + 10t FYM/ha + seed inoculation through PSB and *Trichoderma*	Singh *et al*. (2015), Kashyap *et al.* (2017)
Plant height, leaf area index and dry matter	75% RDF along with vermicompost and seed inoculation through *Azotobacter*	Singh and Pallavi (2019)
Plant height, leaf area index, root length and weight	75% N through urea + 25% N through vermicompost	Biswas *et al*. (2019a)
Dry matter accumulation and crop growth rate		Biswas *et al*. (2019b)

Table 2: Yield attributes and yield of oat as influenced by various INM options

Yield attributes and yield influenced	**INM options**	**References**
Green forage and dry matter yields	25% N through FYM + 50% of RDF through inorganic sources + green manure	Hembram and Kundu (2016)
	50% RDF + vermicompost and FYM each @ 2.5t/ha	Sharma *et al*. (2004)
	100% RDF + 5t vermicompost/ha	Godara *et al*. (2012)
	Biofertilizers seed inoculation + inorganic N	Singh *et al.* (1996)
	120 kg N/ha + seed inoculation through *Azotobacter*	Patel *et al*. (2010)
	50% N (urea) + 50% N through poultry manure	Iqbal *et al*. (2014)
	75% RDF + 5t FYM/ha + 20 kg S/ha	Pandey (2018)
	50% RDF + vermicompost and FYM each @ 5t/ha.	Jayanthi *et al*. (2002), Sheoran *et al.* (2005), Kumar and Dhar (2006)
	100% RDF + vermicompost @ 5 t/ha + seed inoculation through *Azotobacter* @ 2kg/ha	Rawat and Agrawal (2010)
	80 kg N/ha + seed inoculation through *Azotobacter*	Sheoran *et al*. (2002)
	Azotobacter seed inoculation + inorganic nitrogen	Agarwal *et al*. (2002)
	PSB seed inoculation + inorganic nitrogen	Sharma and Verma (2004)
	100% RDF + *Azotobacter* + PSB	Deva (2015a,b,c)

Green forage yield	150% RDF + FYM @ 5t/ha	RVSKVV (2014)
	80 kg inorganic N/ha + FYM @ 5t/ha + seed inoculation through *Azotobacter*	Singh and Dubey (2007, 2008)
	Azotobacter as seed inoculant + inorganic nitrogen	Rawat and Hazra (1997), Mahale *et al*. (2003)
	FYM or poultry manure as substitute of certain part of RDF	Ahmad *et al.* (2011)
Dry matter yield	120 kg N/ha + seed inoculation through biofertilizer	Das and Sheoran (1995)
	100 kg N/ha + *Azotobacter* seed inoculation + sheep manure @ 10 t/ha	Sharma (2009)
Fodder yield	100% FYM or 50% RDF + 50% through FYM	Khan *et al*. (2013)
	75% RDF + vermicompost @ 10 t/ha	Singh *et al.* (1998)
	75% inorganic N + 25% N through FYM + 20 kg $ZnSO_4$/ha	Joshi *et al*. (2007)
Biological and grain yields	50% organic + 50% inorganic nutrients	Khan *et al.* (2014)
Yield attributes and grain yield	75% of N through urea + 25% through vermicompost	Biswas *et al*. (2020a)
	Inorganic nitrogen + *Azotobacter* seed inoculation	Sheoran *et al*. (2000)
Panicle length, panicle/m^2, grains/panicle, test weight, grain and straw yields	15 t FYM/ha + 40 kg phosphorus/ha + 10 kg zinc/ha	Khanday *et al*. (2009)
Spike length, 1000 grain weight, grain yield, straw yield and harvest	50% of RDF + 10 t FYM/ha + seed inoculation through PSB and *Trichoderma*	Singh *et al*. (2015), Kashyap *et al*. (2017)

index		
Ear length, effective spike number, grain number/spike, 1000 grain weight, biomass yield and harvest index	50% inorganic N + 50% organic N + microbial fertilizer	Khan *et al*. (2019)
Green fodder yield, panicles length and number, grains/panicle, 1000 grain weight, grain yield, straw yield and harvest index	120 kg N/ha + vermicompost @ 10t/ha + seed inoculation through *Azotobacter*	Devi *et al*. (2014)
Seed and straw yields	Seed inoculation through *Azotobacter* + FYM	Verma *et al*. (2016)
	Seed inoculation through *Azotobacter* + 75:40 kg N:P_2O_5/ha	Singh *et al*. (2005), Karwasra *et al*. (2007)

Table 3: Quality parameters of oat as influenced by various INM options

Quality parameter(s) influenced	INM option(s)	Key observation(s) (If any)	References

Crude protein (CP)	50% inorganic N + 50% N through vermicompost/ FYM	As effective as 100% RDF in oat-pea intercropping system	Chongloi and Sharma (2018)
	50% RDF + vermicompost and FYM each @ 5t/ha		Jayanthi *et al*. (2002), Kumar and Dhar (2006)
	25% N through FYM + 50% of RDF through biofertilizer + green manure 25% N through FYM + 50% of RDF through inorganic sources + green manure	Both were equally effective	Hembram and Kundu (2016)
	75% RDF + 5t vermicompost/ha	As effective as 100% RDF + 5t vermicompost/ha	Godara *et al*. (2012)
	75% RDF + 5t FYM/ha + 20 kg S/ha		Pandey (2018)
	50% RDF + FYM @ 10t/ha	Improvement of nitrogen content of soil after cultivation of *Khraif* rice through INM directly influenced quality of succeeding crop oat	Roy *et al.* (2009)
	50% or 75% RDF + rest N through vermicompost + seed inoculation through *Azotobacter*	As effective as 100% RDF	Singh and Pallavi (2019)

	120 kg N/ha + seed inoculation through *Azotobacter*		Patel *et al.* (2010)
	100% RDF + vermicompost @ 5 t/ha + seed inoculation through *Azotobacter* @ 2 kg/ha		Rawat and Agrawal (2010)
	100 kg N/ha + *Azotobacter* seed inoculation + sheep manure @ 10 t/ha		Sharma (2009)
	75% N (urea) and 25% N through vermicompost		Biswas *et al.* (2020b)
	Azotobacter, PSB + 75% of N and P + 100% of K and Zn *Azotobacter* + 75% of N and 100% of P, K and Zn	Influenced CP of oat grain and straw, respectively	Jena *et al.* (2018)
Crude protein and fiber	75% inorganic N + 25% N through FYM	As effective as 100% RDF	Tiwana *et al.* (2017)
Crude protein, fiber and total ash contents	50% N (urea) and 50% N through poultry manure	Almost equally effective as 100% inorganic N	Iqbal *et al.* (2014)
	FYM or poultry manure as substitute of certain part of RDF		Ahmad *et al.* (2011)
Crude protein and dry matter digestibility	80 or 120 kg N/ha + seed inoculation through biofertilizer	80 or 120 kg N/ha influenced CP and dry matter digestibility, respectively	Das and Sheoran (1995)
Succulence and	100% RDF + seed inoculation through PSB and	Indicated high moisture content and nitrogen	Deva (2015c)

crude protein	*Azotobacter*	concentration of plant	
Tissue nitrogen, ash and crude protein contents	75% inorganic + 25% organic or 50% inorganic + 50% organic sources of nutrients	As effective as 100% RDF	Khan *et al*. (2013)

Table 4: Influence of various INM options on soil and oat plant status

INM options	Changes in soil and plant status	References

FYM and/or seed inoculation through PSB and/or *Trichoderma* + 50% RDF	Reduction in post-harvest soil pH and improvements of organic carbon, available nitrogen, phosphorus and potassium	Singh *et al.* (2015), Kashyap *et al.* (2017)
100% RDF + seed inoculation through PSB (phosphorus solubilizer) and *Azotobacter* (atmospheric nitrogen fixer*)*	Improvements of post-harvest soil organic carbon, available nitrogen, phosphorus and potassium	Deva (2015a and 2015b)
Inoculation of oat seeds through PSB and *Azotobacter*		Sharma and Verma (2005)
80 kg N/ha + FYM @ 5t/ha + seed inoculation through *Azotobacter*	Improvements of post-harvest soil organic carbon and porosity	Singh and Dubey (2007)
INM incorporating seed inoculation through *Azotobacter* + FYM	Improvements in N, P, K uptakes by oat	Verma *et al.* (2016)
120 kg N/ha + vermicompost @ 10t/ha + seed inoculation through *Azotobacter*		Devi *et al.* (2010)
75% inorganic N + 25% N through FYM		Tiwana *et al.* (2017)
100% RDF + seed inoculation through PSB and *Azotobacter*		Deva (2015b)

100 kg N/ha + seed inoculation through *Azotobacter* + sheep manure @ 10 t/ha	Improvements in N, P, K uptakes by oat and post-harvest soil organic carbon and available nitrogen	Sharma (2009)
50% RDF + vermicompost and FYM each @ 5t/ha		Kumar and Dhar (2006)
75% RDF + 5t FYM/ha + 20 kg S/ha	Improvements in N, P, K, S, Fe, Cu, Zn uptakes by oat as well as post-harvest soil organic carbon, nitrogen, phosphorus, potassium, sulphur and reduction in soil pH	Pandey (2018)
50% inorganic N + 50% N through vermicompost	Improvements in N, P, K, Fe and Zn uptakes by oat	Chongloi and Sharma (2018)
50% N through chemical source + 50% N through organic and microbial fertilizer sources	Improvements in N, P, K uptakes by oat and increments in post-harvest soil pH, organic carbon, dissolved organic nitrogen, dissolved organic carbon, microbial biomass carbon and microbial biomass nitrogen	Khan *et al*. (2019)