International Journal of Plant & Soil Science

Volume 35, Issue 11, Page 147-159, 2023; Article no.IJPSS.99016
ISSN: 2320-7035

Exploring the Effects of Nutrient Management on Growth Attributes, Fodder Qualities and Soil Properties of Fodder Oats (*Avena sativa*): An Overview

Piserla Manasa Reddy [a], Sourabh Kumar [a*], Neeraj Sharma [a], Kathi Hemasri [a], S. K. Nandana [a], Onkar Ramachandra Hirwe [a] and Rajeev [a]

[a] Lovely Professional University, Phagwara, Punjab-144402, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2023/v35i112956

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/99016

Review Article

Received: 18/02/2023
Accepted: 26/04/2023
Published: 06/05/2023

ABSTRACT

Livestock is a significant economic contributor to a country and is essential to the production of milk, eggs and meats for the country's expanding population. Fodder oats (*Avena sativa L.*) are commonly grown for livestock feed due to their high yield potential and nutritive value. Nutrient management is a crucial aspect of fodder oats production that can significantly affect plant growth, forage quality and soil properties. Fodder oat growth attributes are determined by various factors, including nutrient availability, soil fertility and environmental conditions. Adequate soil fertility and pH levels are necessary for optimal nutrient uptake and utilization by plants. Fodder quality is a

**Corresponding author: E-mail: kskumarsourabh4@gmail.com;*

critical determinant of the nutritional value of oat forage. The nutrient content and digestibility of oat forage are influenced by several factors such as plant maturity, environmental conditions and nutrient management practices. High-quality forage is characterized by high crude protein (CP) content, low fiber content and high digestibility. Nutrient management also affects soil properties which can influence plant growth and development. Excessive nutrient application rates can lead to soil nutrient imbalances, soil acidification and reduced soil microbial activity. These effects can lead to reduced nutrient availability and uptake by plants, reduced soil fertility and decreased plant growth. Proper nutrient management such as balanced nutrient application rates and use of organic amendments can enhance soil fertility, improve soil structure and promote plant growth.

Keywords: Livestock; nutrient; oats; fodder; soil fertility.

1. INTRODUCTION

The backbone of the Indian economy is agriculture and 54.6 percent of Indians still rely on it [11]. In the production of food grains, India self-sufficient. The country's present food grain production successfully satisfies the rising need of the continually expanding human population. The demand for fodder is at an all-time became high at the same time that the demand for food grains is rising. Additionally, the lack of fodder has become worse as a result of the recent rapid decline in pasture areas and grassland as well as the poor management of the existent pastures [44]. The primary source of livestock wealth and the foundation of the livestock industry are forages. The lack of grazing resources and green forages in the nation has caused livestock to consistently suffer from malnutrition, resulting in a sub-optimal level of production potential in comparison to other nations. The double crops could be cultivated such that green fodder for livestock and grain for consumption for humans and can be obtained from the same crop for meeting the need of food grains from an expanding population and reduce the pressure on pastureland. In the year 2025, there may be a 64.9 percent shortage of green fodder and a 24.9 percent scarcity of dry fodder. In these conditions, improving the forage resources is the only option to close the supply-demand gap for fodder. Oats are an essential crop for winter feed and forages. It is a potential fodder crop because of its superior habit of growth, greater regenerative capability and great fodder quality [52]. Oat (*Avena sativa* L.) is the annual plant gramineae family. It is a very important feed crop and it is sown at the time of October & November. North-Western India also has oat farms that are rain-fed. Owning to the germination, tillering, booting and heading stages of growth oat needs a cold environment. It often reaches heights of 155–165 cm, barely over wheat and has long, succulent leaves. It fits into the dairy production programme because of its great palatability and cooling effect on [10]. When collected at the 50% flowering stage, its fodder comprises crude protein is 10-11.5%, neutral detergent fibre (NDF) is 55-63 %, 30-32 % acid detergent fibre (ACD), 22.0% to 23.5% cellulose and 17-20 % hemicellulose. As straw, hay, or silage, oat is also used. Oats are successfully produced in the hilly regions and plains of the nation because they need a long cool season for growth. The oat plant thrives in moderate climates. Its best growth occurs in regions with winter temperatures between 15 and 25°C. Although it can endure some frost, hot and dry circumstances have a negative impact on its fodder quality and yield [11]. Oats are cultivated both in tropical and temperate climates due to its characteristics. Oats are a significant winter fodder crop in India's northern and northwest due to its great growth characteristics, fast regrowth and value as a source of dietary protein. In 2 to 3 cuttings, it produces succulent and palatable fodder [16]. Hence, Oats can be successfully grown as multiple-cut fodder. In winter oats are sown as a dual-purpose crop that may be harvested for both grain and temporary winter grazing [40]. Owing to an increase in the number of cattle and agricultural rotation practises that provide limited room for the growth of green forages, the scarcity of fodder crops is getting worse by the day. As a result, it essential to improve yield of high-quality feed and in the irrigated areas of northern India as oat is one of the significant Rabi fodder crops. [88] Oats provide a number of benefits, including early availability of fodder, nutritious fodder, high yield potential, palatability, a strong capacity for regeneration and a greater dry matter content. It is an excellent source of calories, protein, iron, phosphorus and vitamin B. Additionally, as a hay oat can be used and silage for feeding animals when there is a shortage of available fodder. Oats can be a cost-effective source of dietary protein because, when managed for cutting from

Fig. 1. Growth of fodder Oats under different nutrient management

December to April, they produce luscious and extremely tasty fodder [51]. Oats have a lot of potential to increase the quality of the country's available fodder, which will directly enhance the health and milk capacity of milch animals. Additionally, feeding milch animals' high-quality fodder will significantly raise the quality of their milk, which will ultimately enhance human health. In addition, oats are consumed by humans because they yield high-quality grains that may be used to make flooring, oat meal, cookies and other products with a variety of uses. Hence, we are presenting some of the effects of nutrient management on different properties of oat based cropping system.

A husbandry practise known as intercropping involves growing many crops on the same plot of land at the same time. Intercropping is a cultural practise that increases yield stability because it is unlikely that weather variability would affect every crop equally in a mixed cropping system. With complementing canopies and roots systems, crops with diverse growth patterns may have varied environmental needs. They can sometimes make better use of water, nutrients and light than monocultures can. There is evidence that using intercrops as animal feed can increase overall productivity. In various regions of the world, intercropping has been done in a number of methods based on the producer's need, such as hay, silage, grazing, or green chop.

- **Effect on growth and yield attributes of oat due simultaneous cultivation of crops in same field and time**

One of the key justifications for implementing such a system is to deliver a balanced feed supply for diverse livestock production needs. Intercropping with legumes can increase the yield of forage oats. Legumes such as alfalfa, clover or astragalus can bind atmospheric nitrogen and make it available to oats, improving their growth and yield [35]. Intercropping can help suppress weeds and reduce the need for herbicides. Indeed, companion crops can compete with weeds for resources, reducing their growth and spread [56]. The impact of intercropping on forage oats depends on the specific crop used and the management practices used. For example, if legumes are intercropped too aggressively, they can outcompete oats for nutrients and sunlight, reducing overall crop yields. Additionally, some legumes can produce allelopathic compounds that inhibit the growth of oats [99]. Proper selection and careful management of intercropping partners can maximize the benefits of intercropping while minimizing its negative impacts. Intercropping has proven to be a sustainable agricultural practice that increases productivity, reduces the incidence of pests and diseases and improves soil fertility. Forage intercropping oats with legumes such as clover, astragalus and peas has been extensively studied and shown to increase dry matter yield, protein content and the digestibility of forage grasses. Indeed, legumes can fix nitrogen in the atmosphere and improve the nitrogen status of the soil, thus improving the quality of pastures. Furthermore, intercropping with legumes can also promote biodiversity and reduce the occurrence of pests and diseases. As example, a work by Moragues [63] reveal that intercropping forage oats with legumes increased pasture yield and protein content. Forage intercropping oats with Brassica species such as radishes, turnips and kale has also been studied and shown to increase yield and protein content of pastures. For example, a study by Cazzato [22] found that intercropping radish and forage oats increased pasture yield and protein content, but also resulted in high nitrate levels. Forage intercropping oats with cereals such as wheat, barley and rye also have advantages. Cereals can supplement nutritional requirements and provide additional biomass, but result in lower protein content in the diet. A work conducted by [90] found that intercropping forage oats with wheat increased crude protein content and yield of dry matter of fodder grasses. Oat can be used as fodder and mixed with a legume like a pea, berseem or vetch [91]. Legumes and oats work well together to control weeds, prevent disease and use more of the available resources by enhancing the crop's nutritional value in comparison to oats alone [91]. Intercropping is a long-established technique that is frequently employed in low-input cropping systems around the world [8]. As a result of external inputs use, particularly fertilisers, crop production in the 20th century transitioned from being primarily labor-intensive to being more optimised [30]. Because of the increased awareness of environmental deterioration brought on by the intensive use of non-renewable resources, intercropping systems have gained popularity in industrialised nations. Several important benefits of intercropping systems, particularly cereals with legumes, include improved soil conservation [8], a higher total yield and better land use efficiency [33], yield stability of the cropping system, better utilisation of light, water and nutrients [45] and improved pest and weed management [9,33]. The traditional method of growing annual crops such as peas and grasses such as oat in mixed is known as intercropping. Oats are a staple in the production of hay, pasture and silage for livestock and are frequently farmed either by themselves or in combination with other grains Cazzato [58]. There have been several findings indicating that combining pea and oat yields boosted hay production. The amount and quality of the hay are both improved by inter-cropping oats crop with fodder legumes such as vetch [49]. According to various studies, crossbred cows (*Bos taurus Bos indicus*) produced more milk when oat-vetch hay was supplemented with a high or concentrates fodder legume hay [49]. Akhtar et al. [6] examined the effects of nano urea on the growth and yield of oat plants under drought stress conditions. The researchers found that nano urea improved the growth and yield of the plants, as well as their water use efficiency, compared to traditional urea fertilizer. They suggested that the improved performance of the oat plants could be due to the smaller particle size and more uniform distribution of nutrients in the nano urea. They looked at the effects of nano urea on intercropping of maize and cowpea. The researchers found that nano urea improved the growth and yield of both crops and also increased the nitrogen use efficiency of the intercropping system. A study by Murtaza [64] investigated the effect of intercropping oat with pea (*Pisum sativum*) and lentil (*Lens culinaris*) on growth and yield attributes in Pakistan. The study found that intercropping oat with pea resulted in a significant increase in oat grain yield, while intercropping with lentil resulted in a significant increase in oat biomass yield. Similarly, a study by Ngouajio [66] evaluated the effect of relay intercropping oat with soybean (*Glycine max*) and cowpea (*Vigna unguiculata*) in the United States. The study found that intercropping soybean or cowpea with oat resulted in a significant increase in oat grain yield, while having no negative impact on the yield of the companion crop. In contrast, a study by Jahan [43] found that oat yield was significantly lower in the intercropped treatment compared to the sole oat treatment, likely due to competition for resources between the two crops. Another study by Wang [94] evaluated the effect of oat-wheat (*Triticum aestivum*) relay intercropping on growth and yield attributes in China they found that oat-wheat intercropping resulted in a significant increase in oat grain yield, as well as wheat grain yield, compared to the sole crop treatment.

Table 1. Cropping pattern and percentage of crude protein

Cropping Pattern	Crude Protein (%)	Reference
Oats + Pea Oats + Linseed Oats + Toria	13.88% 6.66% 6.60%	Amonge, P., Thakuria, k., & Saikia, j. intercropping of oilseed crops with oat fodder in rice fallows under rainfed condition.
Oats + Lucerne	16.72%	NinamaSD, Shroff JC and Mehta PV (2020) Effect of different row ratios on yield and quality of oat (*Avena sativa* L.) and Lucerne (*Medicago sativa* L.) intercropping.

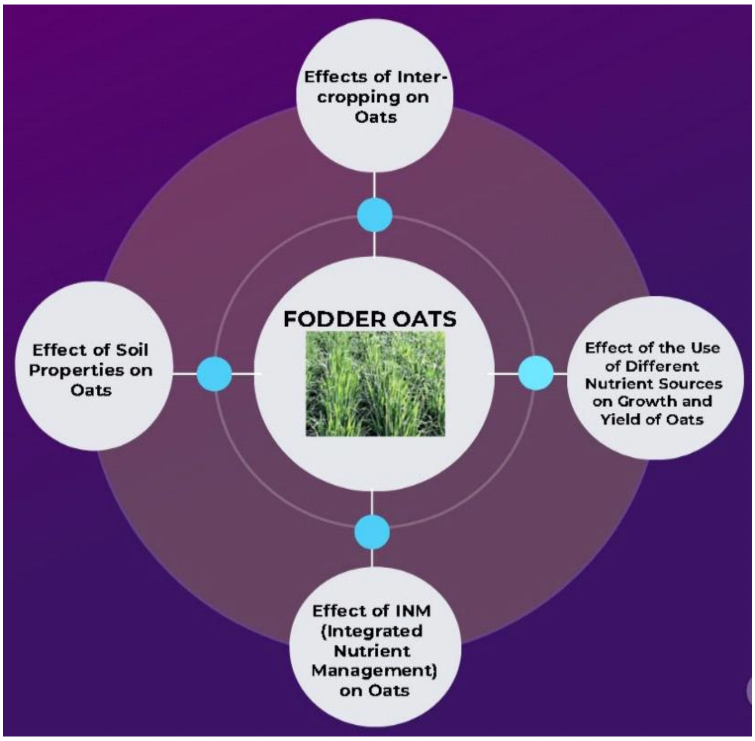

Fig. 2. Analysing the effect of different components on oat cropping system

Fig. 3. Integrated nutrient management approaches

- **Effect of Combined Nutrient application on growth and yield attributes of oats *(Avena sativa)***

Combined use of organic and inorganic nutrients is essential for increasing fertility of soil, which can reduce the need for expensive and ecologically hazardous fertilisers for the current and following crops [17]. In addition to supplying organic materials, organic sources such poultry manure (PM), farm yard manure (FYM), compost, green manuring and among others, also improve the soil fertility condition [23]. Manures provide the necessary nutrients and also enhance the chemical and physical characteristics of the soil [85]. Chemical fertilisers are an essential component of contemporary crop production techniques. Chemical fertilisers cannot be completely replaced by other methods [65]. The combination of inorganic and organic nutrient sources provided necessary nutrients and also had some beneficial interactions with chemical fertilisers to boost their effectiveness and so lowers environmental hazard [3]. Singh [87] performed to evaluate the effect of nutrient management on yield, quality and nutrient uptake of oats in northern India. They found that combing the organic and inorganic sources significantly increased the yield, quality and nutrient absorption of oats compared to the control treatment. Jha [47] performed an experiment to investigate the effect of INM on fodder yield, soil quality and fertility of an oat farming system in India. They found that use of combined nutrients significantly increased soil fertility parameters as well as yield and forage quality compared to control treatments. Kaur [48] evaluated the effect of INM on quality, yield and nutrient uptake in oats they found that integration of nutrients significantly increased oat yield and nutrient uptake compared to the control treatment, while quality parameters were not significantly affected. Fathi [34] conducted a study to investigate the effects of different organic and inorganic treatments on oat yield, quality and nutrient uptake. They found that the combination of chemical fertilizer and organic fertilizers gave oats the highest yield, quality and nutrient uptake compared to other combined treatments. Choudhary [28] conducted a study in India to assess the effect of integrated nutrient management on oat yield, quality and nutrient uptake. They found that INM significantly increased oat yield and nutrient uptake compared to the control treatment, but there were no change quality parameters significantly. After rice was cultivated in kharif using 50% RDF combined with FYM at 10t/ha, [76] observed significant nutrient uptakes of oat grown in residual soil fertility. Sharma [84] applied 50% RDF along with vermicompost and FYM each at 2.5t/ha to achieve the highest level of economic viability for oat cultivation, which was followed closely by application of 50% RDF along with vermicompost at 2.5t/ha. By applying 80 or 120kg N/ha along with vermicompost @ 10t/ha and inoculation of seed through Azotobacter and compared to the control, [32] obtained higher gross and net returns from oat cultivation. With 100% RDF, vermicompost at 5 t/ha, seed inoculation with biofertilizer (azatobacter) at 2 kg/ha and seed inoculation, [74] also achieved good economic return from oat field. According to [31], 100% RDF application together with seed inoculation using PSB and Azotobacter produced the maximum net realisation and BC ratio in oat production. Patel [71] found that oat cultivation had a good net financial return when 120 kg of nitrogen per hectare was applied and seeds were inoculated with Azotobacter. The application of 150kg N ha^{-1} along with inoculation of seed through Azotobacter and PSB. Sharma [83] obtained maximum net returns and returns per rupee spent; however, the energy productivity and energy ratio were obtained with the usage of 100 kg N ha^{-1}, seed inoculation through Azotobacter and sheep manure at 10 t/ha. [82] discovered that oat had high economic viability, energy responsiveness, energy productivity and energy ratio with the usage of 100 kg N ha^{-1} along with inoculation of seed through Azotobacter and PSB. Salem [80] investigated the effect of using combined sources of nano urea and compost on the growth and yield of maize. The study found that the combined use of nano urea and compost significantly increased maize growth and yield compared to using either input alone. Gholami [36] found the effect of using combined sources of nano urea and biochar on the yield and quality of maize. The study found that the combined use of nano urea and biochar significantly increased maize yield and quality compared to using either input alone. A study by Raza [75] investigated the effect of the combined application of organic and inorganic fertilizers on the growth and yield of oats. The study found that the application of farmyard manure and NPK fertilizers significantly increased the plant height, tiller number and dry matter yield of oats compared to the use of chemical fertilizers alone. A study by Hashemi [39] evaluated the effect of the combined application of cattle manure and NPK fertilizers on the grain yield and harvest index of oats. The study found that the application of the combined fertilizers resulted in a significant increase in grain yield and harvest index compared to the use of chemical fertilizers alone. In a study by [68], the effect of the combined application of organic and inorganic fertilizers on the beta-glucan content of oats was evaluated he found that the application of a combination of compost and NPK fertilizers significantly increased the beta-glucan content of oats compared to the use of chemical fertilizers alone. Similarly, a study by Collins [29] study found that the application of a combination of organic and inorganic fertilizers resulted in a significant increase in protein and fiber content of oats compared to the use of chemical fertilizers alone.

- **Effect on soil properties due to cultivation of Oats (*Avena sativa*)**

An essential component of Indian soil is the management of nutrients**.** The organic substrate for plant growth is called soil and it directly affects the quantity and quality of crops. A natural habitat for plant growth that includes minerals, organic matter and living things makes up soil [19] which differ in their biological, morphological and physiochemical characteristics [67]. Saini [78] found that soil pH had a significant effect on forage oat growth and yield his results shown that a soil pH of 6.5 gives the highest yields. Saleem [79] obtained a significant positive correlation between soil organic matter and yield. Studies have shown that yields are highest when the soil organic matter content is 2.5%. also, [37] reported the effect of soil moisture on the yield and growth of forage oats he found that yields are highest at 80% soil moisture. Singh [86] investigated the effect of soil nutrients on the growth and yield of forage oats. The study found that the additions of nitrogen(N), phosphorus(P) and potassium(K) significantly increased the forage yield of oats. The soil quality of Punjab and its potential as a marker for various land uses were the focus of [92] research. The scientist observed that the pH of the soil's ranges from neutral to alkaline. Between 6.5 and 9.4 is the pH range. Liu [57] studied the level of soil fertility in a few villages in the Punjabi province of Hoshiarpur, according to the study, pH indicates that nature is neutral to severely alkaline. The range of the EC in soil samples is 0.16 to 0.67 mmhos/cm. Yadav [98] conducted research on the fertility of the Punjab soils as the soil depth is increased, the organic carbon content in the top soil layers decreases. The optimum soil pH for oats is between 6.0 and 6.5, with pH values below 5.5 or above 7.0 causing reduced growth and yield due to a deficiency in nutrients and aluminum toxicity [94]. Proper application of nitrogen(N), phosphorus (P) and potassium(K) fertilizers is very crucial for optimum oat yield and growth. The optimal rates of N, P and K were found to be 90, 45 and 90 kg/ha respectively [5]. Soil compaction can limit root growth and reduce nutrient uptake, reducing oat growth and yield. Research has shown that soil compaction can be mitigated through the adoption of cover crops reduced tillage and proper management of soil organic matter [20]. Adequate soil moisture is very important for optimum oat growth and yield, studies have shown that water stress can significantly reduce oat growth and yield and the optimum soil moisture content for oat growth is 60% to 80% of the water capacity of the field [14, 21]. Oats prefer cooler temperatures and high temperatures (>25°C) during the vegetative phase led to reduced growth and yield, studies have shown that the optimum soil temperature range for oat growth is between 15°C and 20°C [35]. Oats grown in loamy soils produced significantly more than those grown in sandy loam soils, according to an Indian study. This is probably because loamy soils have a greater capacity to hold water and are more nutrient-rich [59]. An additional study done in India discovered that using farmyard manure to increase soil organic matter greatly increased oats' grain yield and nutrient content, with the greatest yield being attained at a rate of 10 tons/ha of manure [81]. According to research done in India, oats produce more grain when phosphorus fertiliser is applied, with the ideal rate being 60 kg/ha of phosphorus [89]. Soil pH levels between 6.0 and 7.0 are ideal for oat growth and yield, with pH levels below 5.5 or above 8.0 leading to decreased growth and yield due to nutrient deficiencies and aluminium toxicity [15]. Maintaining soil moisture at 80% of field capacity during the growing season significantly increased yield and nutrient content of oats compared

Table 2. List of treatments use for gross and net returns

Treatment	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B C Ratio	Reference
Oats (sole)	84282	49719	2.43	NinamaSD, Shroff JC and Mehta PV (2020) Effect of different row ratios on yield and quality of oat (*Avena sativa* L.) and Lucerne (*Medicago sativa* L.) intercropping
Oat+Lucerne	81692	45860	2.28	Ninama SD, Shroff JC and Mehta PV (2020) Effect of different row ratios on yield and quality of oat (*Avena sativa* L.) and Lucerne (*Medicago sativa* L.) intercropping
Oat+Berseem	102760	69790	1.47	Muskan Porval (2021) Effect of nano Zinc and Oat+Berseem intercropping on fodder yield and Quality.

to oats grown in the field. Water stress conditions [2]. Saberali [77] reported that the application of nano urea to fodder oats increased soil nitrogen and phosphorus content, as well as soil organic matter content. Jafari [41] found that the use of nano urea improved soil properties such as soil organic matter and available phosphorus in oats compared to conventional urea. Hasanuzzaman [38] reported that the use of nano urea increased soil organic matter and improved soil fertility in oats. A study by Choudhary [27] evaluated the effect of long-term oat cultivation on soil properties in a semi-arid region of India. The study found that oat cultivation resulted in a significant increase in soil organic carbon, total nitrogen, available phosphorus and exchangeable potassium compared to the fallow treatment. Similarly, a study by Li [55] investigated the effect of oat cultivation on soil properties in Northeast China study found that oat cultivation increased soil organic carbon, total nitrogen and available phosphorus, while reducing soil bulk density and increasing soil water holding capacity. Abbas [1] reported a decrease in soil organic carbon, total nitrogen and available phosphorus in response to oat cultivation in Pakistan the study also noted that these negative effects were offset by the positive impact of oat cultivation on soil water content and aggregate stability. Gao [35] evaluated the effect of oat cultivation on soil microbial biomass and activity in North China. found that oat cultivation increased soil microbial biomass carbon and nitrogen, as well as soil enzyme activity, indicating a positive impact on soil health.

- **Effect of B:C ratios by the effect of oat *(Avena sativa)* cropping system**

According to Jayanthi [46], the usage of combination sources of inorganic and organic fertilisers resulted in a larger no.of tillers per square metre in the oats crop. When vermicompost was combined with inorganic nutrient sources the oat variety "OS6" produced the greatest results in terms of growth characteristics. Chellamuthu [25] found that applying biofertilizer together with 75% of the required nitrogen fertiliser increased plant height compared to applying 100% NP alone. The treatment that received no fertiliser showed a minimum dry weight of 2.97 g per tiller (control). The highest leaf area plant-1 (128 cm^2) was obtained by applying inorganic fertiliser NP at a rate of 150::60 kg ha^{-1} compared to the other treatments according to Chaudhary [24]. Adding vermicompost and farmyard manure dramatically raised oat plants' height, number of tillers and dry matter output [53]. Using compost enhanced oat plant height, leaf area and chlorophyll content [61]. The usage of nitrogen fertiliser can increase the growth characteristics of fodder oats, leading to higher yields and better-quality feed. Fodder oats have been reported to exhibit good growth qualities including high tillering ability, early vigour and quick growth rate [62]. Adding nitrogen fertiliser to the soil greatly raised the output of oats feed. The application of 120 kg ha^{-1} of urea resulted the maximum yield [93]. A study by Ramesh [73] evaluated the impact of different cropping systems on the benefit-cost (B:C) ratio of oat cultivation in India. The study found that the highest B:C ratio was obtained from the oat-potato cropping system, followed by oat-onion and oat-garlic cropping systems. The lowest B:C ratio was observed in the oat-fallow cropping system. Similarly, a study by Khan [50] assessed the economic feasibility of oat cultivation under different cropping systems in Pakistan. The study found that the oat-maize cropping system resulted in the highest net income and B:C ratio, followed by oat-wheat and oat-fallow cropping systems. In a study by Zhi [100], the effect of different fertilization levels on the B:C ratio of oat cultivation was evaluated in China. The study found that the application of moderate levels of nitrogen and phosphorus fertilizers resulted in the highest B:C ratio compared to no fertilizer or excessive fertilizer application. Similarly, a study by Chen [26] evaluated the impact of different irrigation levels on the B:C ratio of oat cultivation in arid regions of China. The study found that the highest B:C ratio was obtained under the deficit irrigation regime, followed by the full irrigation regime. The lowest B:C ratio was observed under the excessive irrigation regime.

2. CONCLUSION

In conclusion, nutrient management practices have a significant impact on the growth attributes, fodder qualities and soil properties of fodder oats (*Avena sativa*). Proper nutrient management, including the application of fertilizers and organic amendments, can lead to increased plant growth, higher yields and improved fodder quality. The effects of nutrient management on fodder oats are influenced by various factors, including soil fertility, environmental conditions and plant maturity. Sustainable nutrient management practices that consider these factors and promote soil health are essential for optimal fodder oats production.

These practices can enhance soil fertility, improve soil structure and promote plant growth, ultimately resulting in high-quality forage for livestock feed. Overall, exploring the effects of nutrient management on growth attributes, fodder qualities and soil properties of fodder oats is critical for promoting and improving livestock feed quality. Further research is needed to optimize nutrient management practices for fodder oats production, considering the unique requirements of different soil types, climatic conditions and management systems. Overall, this study highlights the importance of proper nutrient management in the cultivation of fodder oats and the potential benefits that can be gained through sustainable and balanced fertilization practices.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Abbas Q, Hussain M, Saleem MF, Aslam M, Ali A, Nawaz MA. Impact of oat (*Avena sativa* L.) cultivation on soil properties under semi-arid environment of Punjab, Pakistan. Soil Environ. 2018;37(1):35-44.
2. Acharya BK, Panda AK, Pattanaik AK. Effect of soil moisture stress on growth and yield attributes of oats (*Avena sativa* L.). J Pharmacogn Phytochem. 2020;9(3):956-8.
3. Ahmad N, Rashid M, Vaes AG. Fertilizer and their uses in Pakistan. NFDC Publications pp 142-149 and 172-175; 1996.
4. Mushtaq A, Gul-Zaffar ZA, Habib M, Mehfuza H. A review on oat (*Avena sativa* L.) as a dualpurpose crop. Sci Res Essays. 2014;9(4):52-9.
5. Ahmad R, Khan A, Ali A, Muhammad D. Effect of nitrogen, phosphorus and potassium on growth and yield of oats (*Avena sativa* L.). Int J Agric Biol. 2016;18(3):484-8.
6. Akhtar MJ, Iqbal MA, Ahmad I, Ijaz M. Nanourea improves growth, yield, and nitrogen use efficiency of maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* L.) intercropping. J Plant Nutr. 2020;43(4):487-99.
7. Altunok M, Arslan M, Altunok H. The effects of soil texture and irrigation on the yield, quality and mineral content of oat (*Avena sativa* L.) grown forage. Agric Water Manag. 2020;230:105987.
8. Anil L, Park J, Phipps RH, Miller FA. Temperate intercropping of cereals for forage: a review of the potential for growth and utilization with particular reference to the UK. Grass and Forage Science. 1998;53(4):301-17.
9. Banik P, Midya A, Sarkar BK, Ghose SS. Wheat and chickpea intercropping systems in an additive series experiment: advantages and wesmothering. Eur J Agron. 2006;24(4):325-32.ience, 53(4), 301-317.
10. Anonymous. Handbook of agriculture. Indian Council of Agricultural Research. 2007;1354-7.
11. Anonymous. Forage crops and their management. Jhansi: Indian Grassland and Fodder Research Institute-284003; 2012.
12. Anonymous. Annual Report. Department of agriculture, cooperation & farmers welfare ministry of agriculture & farmers welfare government of India; 2018.
13. ao, X, Wang Y, Zhang X, Shi X, Chen Y, Wang Y. Effects of intercropping with faba bean on the growth and yield of forage oat in the Loess Plateau of China. Grassl Sci. 2020;66(1):18-26.
14. Asgari M, Khazaei HR, Jahansooz MR, Sabaghnia N. Effect of drought stress and nitrogen application on grain yield, yield components, and protein content of oat (*Avena sativa* L.). J Agric Sci. 2018;10(7): 58-69.
15. Babu R, Kumar A, Rana SS, Kumar S, Dhyani D. Effect of soil pH and nitrogen on yield and nutrient uptake of oats (*Avena sativa* L.) under acid alfisols of mid hills of Himachal Pradesh. Int J Curr Microbiol Appl Sci. 2020;9(10):3219-25.
16. Bhilare RL, Joshi YP. Productivity and quality of oat (*Avena sativa*) in relation to cutting management and nitrogen levels. Indian J Agron. 2007;52:247-50.
17. Biswas S, Jana K, Agrawal RK. Puste AM. Innov J. 2019a. 2019 Effect of integrated nutrient management on growth attributing characters of crops under various oat-lathyrus intercropping system. The Pharma;8(9):368-73.
18. Bondada BR, Syvertsen JP, Albrigo LG. Urea nitrogen uptake by citrus leaves. Hort Sci. 2001;36(6):1061-5.

19. Buckman HO, Brady NC. The nature and properties of soils. Soil Science. 1960;90(3).
20. Caviglia OP, Melchiori RJ, Duarte GF, Barbera AC. Cover crops and their management in no-till systems of the Argentine Pampas. Soil Till Res. 2017;165:25-33.
21. Caviglia OP, Sadras VO, Andrade FH, Zhang R. Soil water and nitrogen interactions with oat; 2018.
22. Cazzato E, Fornasier F, Tabacco E, Borreani G, Scaglioni L. The use of Brassica forage crops in combination with forage oats: yield, quality and safety aspects. Italiaanse Tydskr Agronomie. 2017;12(3):206-11.
23. Chang C, Sommerfeldt TG, Entz T. Soil Chemistry after eleven annual application of cattle feedlot manure. J Environ Qual. 1991;20(2):475-80.
24. Chaudhary RV, Khade ST. Growth and yield analysis of sorghum hybrid as affected by NPK. Ann Plant Physiol. 1991;5:97-102.
25. Chellamuthu V, Khan AKF, Malarvizhi P. Studies on effect of inorganic and biofertiliser on bajranapier hybrid grass. Range Manag Agrofor. 2000;21:135-7.
26. Chen S, Wang H, Zhang Q, Zhan A, Han X. Economic water use efficiency and benefit-cost ratio of oat production under different irrigation regimes in the arid region of Northwest China. Sustainability. 2018;10(11):4021.
27. Choudhary AK, Singh V, Singh RK, Singh RP. Impact of long-term oat (*Avena sativa* L.) cultivation on soil properties under semi-arid region of India. Indian J Agric Sci. 2021;91(3):224-7.
28. Choudhary M, Parihar SS. Effect of integrated nutrient management on growth, yield, nutrient uptake and quality of oats (*Avena sativa* L.) in north-west Rajasthan. Indian J Agric Sci. 2016;86(4): 524-8.
29. Collins HM, Wilcox JR, Rayas-Duarte P. Impact of nitrogen management on oat quality. J Cereal Sci. 2021;99:103235.
30. Crews TE, Peoples MB. Legume versus fertilizer sources of nitrogen: Ecological tradeoffs and human needs. Agric Ecosyst Environ. 2004;102(3):279-97.
31. Deva S. Yield of fodder oat and balance sheet of nutrients influenced by tillage practices and nutrient management. Int J Agric Sci. 2015;11(1):112-5.
32. Devi U, Singh KP, Kumar S, Sewhag (.2014) Effect of nitrogen levels, organic manures and Azotobacter inoculation on yield and economics of multi-cut oats. Forage research. 2014;40(1):36-43.
33. Dhima KV, Lithourgidis AS, Vasilakoglou IB, Dordas CA. Competition indices of common vetch and cereal intercrops in two seeding ratio. Field Crops Res. 2007;100(2-3):249-56.
34. Fathi G, Bagheri AR, Aghaalikhani M, Raeisi Sarjaz M. Effect of integrated nutrient management on yield, quality and nutrient uptake of oats (*Avena sativa* L.). J Plant Nutr. 2019;42(1):1-15.
35. Gao L, Chen X, Zhang W, Tian Y, Zhang J, Cao C. Effect of oat cultivation on soil microbial biomass and enzyme activity in North China. PLOS ONE. 2017;12(11):e0187789.
36. Gholami A, Ghassemi-Golezani K, Valizadeh M, Moghaddam M. Effect of combined application of nano-urea and biochar on yield and quality of maize. J Plant Nutr. 2021;44(10):2029-41.
37. Golchin M, Riahi M, Asgari HR. Effect of soil moisture and irrigation intervals on growth, yield and quality of forage oats. J Plant Process Funct. 2021;9(37):13-23.
38. Hasanuzzaman M, Fujita M. Nano fertilizer: A new frontier for crop fertilization. Adv Plant Crop Physiol. 2020:(387-402).
39. Hashemi SS, Abbasian A, Rezvani-Moghaddam P, Khavazi K. Effects of manure and chemical fertilizers on yield and yield components of oat. J Plant Nutr. 2020;43 (6):733-44.
40. Hussain A, Khan S, Mohammad D. Forage yield and nutritive value of oat cultivar Fatua at various intervals of harvesting. Pak J Agric Res. 2002;17(2):148-52.
41. Jafari S, Kashani A, Rezvani Moghaddam P, Moradi P. Nano-fertilizers and their role in sustainable agriculture: a review. J Plant Nutr. 2019;42(3):265-80.
42. Jafari S, Khazaei HR, Jahansooz MR, Sabaghnia N. Drought stress effect on some physiological and agronomic traits of oat (*Avena sativa* L.) cultivars. Agric Water Manag. 2020;237:106197.
43. Jahan MS, Mahmood N, Haque MM. Yield and quality of oats under maize intercropping system. Int J Sustain Agric Technol. 2018;14(1):39-47.
44. Jat RK, Patel AG, Shviran A, Bijarnia AL. Response of oat (*Avena sativa* L.) to

nitrogen and phosphorus levels under North Gujarat agro- climati conditions. J Eco-Friendly Agric. 2015;10(1):39-42.
45. Javanmard A, Nasab ADM, Javanshir A, Moghaddam M, Janmohammadi H. Forage yield and quality in intercropping of maize with different legumes as doublecropped. J Food Agric Environ. 2009;7(1):163-6.
46. Jayanthi C, Malarvizhi P, Fazullah AK, Chinnusamy C. Integrated nutrient management in forage oat (*Avena sativa*). Indian J Agron. 2002;47(1):130-3.
47. Jha AK, Singh M, Singh KP. Effect of integrated nutrient management on forage yield, quality and soil fertility in oat (*Avena sativa*)-based cropping system. Indian J Agric Sci. 2015;85(3):403-8.
48. Kaur A, Singh M. Effect of integrated nutrient management on yield and quality of oats (*Avena sativa*). Prog Agric. 2015;15(2):227-31.
49. Khalili H, Osuji PO, Umunna N, Crosse S. The effects of forage type (maizelablab or oat-vetch) and level of supplementation (wheat-middlings) on food intake, diet apparent digestibility, purine excretion and milk production of crossbred (Bos taurus× Bos indicus) cows. Anim Sci. 1994;58(3):321-8.
50. Khan IA, Ahmad I, Razaq M, Wahid A, Ahmed S. Net income, yield and benefit-cost ratio of oat under different cropping systems in Pakistan. J Agric Sci. 2018;10(8):69-77.
51. Kumar A. Effect of date of sowing and cutting management on yield & quality of oats (*Avena sativa*) fodder [M.Sc. thesis]. Karnal: National Dairy Research Institute; 2012.
52. Kumar BS, Singh RV. Nutrient availability of soil influenced by nitrogen levels and cutting management in fodder oat (*Avena sativa* L.) cultivation. Int J Chem Stud. 2018;6(3):2057-9.
53. Kumar V, Biswas DR, Tomar RK, Kumar A, Pandey A. Response of oats to organic manures and chemical fertilizers under mid hills of Himachal Pradesh. J Appl Nat Sci. 2021;13(2):571-8.
54. Lal R. Promise and limitations of soils to minimize climate change. J Soil Water Conserv. 2008;63(4):113A-8A.
55. Li X, Tian Y, Jia X, Wang G. Soil quality indicators under different rotations and fertilization regimes in Northeast China. Sustainability. 2019;11(17):4788.
56. Liu B, Guo H, Wang W, Zhu X. Intercropping of alfalfa with oats improves soil fertility and enhances yield and quality of forage crops. J Anim Sci Biotechnol. 2020;11(1):61.
57. Maninder SBS, Ajaib S, Singh A. Evaluation of soil fertility status of adopted villages in Hoshiarpur district of Punjab of soil in East Khasi Hills District. Int J Agric Sci. 2020; 16(1):57-63.
58. McKenzie DB, Spaner D. White lupin: an alternative to pea in oat-legume forage mixtures grown in Newfoundland. Can J Plant Sci. 1999;79(1):43-7.
59. Mishra A, Tripathi RS, Singh SP. Effect of different levels of nitrogen and sulphur on growth and yield of oats (*Avena sativa* L.) in different textured soils. Int J Chem Stud. 2020;8(4):70-4.
60. Moaveni P, Kheiri T. November 25-27, 2011 in Maldives. In: 2nd International Conference on Agricultural and Animal Science. Vol. 22. Singapore: IACSIT Press. 2011;160-3.
61. Mohammadi M, Aliabadi Farahani H, Movahedi Naeini SA. Effect of different levels of compost on growth, yield and yield components of oat (*Avena sativa* L.). J Crop Prod Process. 2020;10(4):17-29.
62. Molla MR, Ghosh SK, Das SK, Hossain MM, Akhter S. Nutritive value, production potential and quality of oat (*Avena sativa*) fodder: a review. Int J Livest Res. 2020;10(11):1-14.
63. Moragues M, Reverter C, Poblaciones MJ. Planting legumes increases grass yield and improves the nutritional value of winter oat grass. Sci Cultures Routes. 2018;69(4):365-76.
64. Murtaza G, Hussain M, Hassan W, Ahmed R, Tahir M. Intercropping oat (*Avena sativa* L.) with pea (Pisum sativum L.) and lentil (*Lens culinaris* L.) for improving growth and yield attributes. Int J Agric Biol. 2018;20(2):379-84.
65. NFDC. Fertilizer recommendation in Pakistan. Planning and development division. Islamabad: NFDC, Government of Pakistan. 1997;7.
66. Ngouajio M, Faghihi J, Cramer G. Relay intercropping oat with soybean or cowpea for sustainable food production in the USA. Int J Agric Sustain. 2015;13(2):129-42.
67. Nongrum N, Swaroop N, David AA, Barthwal A. Assessment of Physical Properties; 2021.

68. O'Leary GJ, Guppy CN, Rebgetz RJ, Knox OG, Wallwork H. Effect of compost and inorganic fertilisers on grain yield, grain protein content and beta-glucan in oats (*Avena sativa* L.). Field Crops Res. 2019;241:107590.
69. Pardo G, Quemada M, Meco R. Organic amendments enhance oat biomass and nutrient uptake in a Mediterranean agroecosystem. Agronomy. 2020;10(6): 794.
70. Pariyar D. Fodder oats in Nepal. In: Suttee JM, Reynolds SG, editors. Fodder oats: A World [review]. Rome: Food and Agriculture Organization. 2002;103-11.
71. Patel MR, Meisheri TG, Sadhu AC. Effect of irrigation, nitrogen and bio-fertilizer on forage yield and quality of oat (*Avena sativa* L.). Forage Res. 2010;35(4):231-5.
72. Pocket book of agricultural statistics. Government of India Ministry of Agriculture and farmers Welfare Department of Agriculture, Cooperation and Farmers Welfare Directorate of Economics & Statistics; 2020.
73. Ramesh T, Bhatia R, Kumar M, Kumar R, Singh VK. Effect of different cropping systems on yield and economics of oat (*Avena sativa* L.) in western Himalayas of India. Indian J Agric Sci. 2021;91(7): 455-9.
74. Rawat A, Agrawal SB. Effect of soil enrichment in conjunction with bioorganics and chemical fertilizers on yield and quality of fodder oat (*Avena sativa* L.). Forage Res. 2010;35(4):190-2.
75. Raza S, Ahmed R, Ali S, Saleem MF, Sarwar A. Response of oat crop (*Avena sativa* L.) to organic and inorganic fertilizers under agro-climatic conditions of Pothwar Plateau, Pakistan. Arch Agron Soil Sci. 2021:1-16.
76. Roy DP, Barik AK, De GC. Production potentiality, economics and nutrient uptake ofwinter fodder crops on residual fertility after wet season rice under IPNS in red and lateritic soil. Forage Res. 2009;35(1):52-5.
77. Saberali SF, Ghalavand A, Seyed Sharifi R, Aghhavani-Shajari M. Impact of nanofertilizer on nutrient uptake of forage oats (*Avena sativa* L.) in different irrigation regimes. Arch Agron Soil Sci. 2018;64(11):1520-31.
78. Saini P, Singh P, Singh R, Singh MK. Response of oats (*Avena sativa*) to nitrogen levels and plant spacing under varying soil pH conditions. Indian J Agric Sci. 2019;89 (11):1822-5.
79. Saleem MF, Anjum SA, Ahmad S. Effect of organic matter on growth, yield and quality of oats (*Avena sativa* L.). J Anim Plant Sci. 2016;26(5):1385-92.
80. Salem MA, Hassanein RA, El-Shafie HA. Effect of nano-urea and compost on growth and yield of maize. J Appl Sci Res. 2018;4(1):1-7.
81. Sarkar MA, Mishra BN, Nayak AK. Response of oat (*Avena sativa* L.) to farmyard manure application on yield and nutrient content in acidic soil. J Pharmacogn Phytochem. 2020;9(4):810-2.
82. Sharma KC. Integrated nitrogen management in fodder oats (*Avena sativa*) in hot arid ecosystem of Rajasthan. Indian J Agron. 2009;54(4):459-64.
83. Sharma KC, Verma RS. Effect of N and P fertilizers and biofertilizers on the yield, marginal rate of return, energy relationship, economics and residual effect on soil in fodder oats (*Avena sativa* L.). Forage Res. 2005;31(2):118-22.
84. Sharma KK, Sharma S, Neog SB. Integrated nutrient management in oat (*Avena sativa* L.). Forage Res. 2004; 29(4):195-7.
85. Sharpley AN, Mcdowell RW, Kleinman PJA. Amounts, forms and solubility of phosphorus in soils receiving manures. Soil Sci Soc Am J. 2004;68(6):2048-57.
86. Singh AK, Pandey RN, Verma M. Response of oat (*Avena sativa* L.) to nitrogen and phosphorus application on yield and nutrient uptake in loamy soil. Indian J Agric Sci. 2020;90(3):51-6.
87. Singh A, Singh RK, Singh Y, Singh UP. Effect of integrated nutrient management on yield, quality and nutrient uptake of oats (*Avena sativa* L.) in North India. Legume Res. 2017; 40(3):529-32.
88. Singh KP, Tomer PS, Singh KP. Nutrition of forage oat under cutting management. Haryana Agric Univ J Res. 1975;5(1): 1-3.
89. Singh S, Singh M, Singh R, Singh J, Singh M. Effect of integrated nutrient management on productivity, quality and economics of oats (*Avena sativa* L.) in subtropical conditions. J Pharmacogn Phytochem. 2020;9(1):63-8.
90. Thakur DK, Sharma D, Kumar D, Kumar S. Effects of cereal and oat (*Avena sativa*) intercropping on forage yield and quality; 2019.

91. Undersander D. Pea and small grain mixtures. Uzun, A., & Açikgöz, E. (1998). Univ Wis Extension Wisc Team Forage Focus Forage. 2003;5(7):1-2
92. Vashisht BB, Maharjan B, Sharma S, Kaur S. Soil quality and its potential indicators under different land use systems in the Shivaliks of Indian Punjab. Sustainability. 2020;12(8):3490.
93. Vivek P, Kumar P, Kumar P, Kumar P, Singh SK, Kumar A. Effect of seed rate and nitrogen levels on growth and yield of oat (*Avena sativa* L.) for forage production. Int J Chem Stud. 2020;8(1):1487-90.
94. Wang J, Li X, Yang G, Du Q, Chen F. Intercropping oat with wheat improves the yield and quality of oat grain under organic farming. Agronomy. 2019;9(12):789.
95. Wang X, Li X, Wang Q, Xu H. The effects of nitrogen, phosphorus and potassium fertilizer on the yield and quality of oat (*Avena sativa* L.). J Northeast Agric Univ (Engl Ed). 2020;27(3):46-52.
96. Xia H, Zhang C, Wang X, Zhang X. Effects of soil pH on the growth and nutrient uptake of oat (*Avena sativa* L.). J Soil Sci Plant Nutr. 2020;20(3):743-52.
97. Yadav BK. Bio-chemical properties and nutrient availability in soil as influenced by in situ paddy residue burning in semi- arid region of Punjab. J Pharmacognosyand Phytochem. 2020;9 (4):1275-83.
98. Yadav BK, Sidhu AS, Kumar. INDIA, D. Bathinda District of South-West Punjab; 2016.
99. Yan H, Liu H, Yu L. Intercropping effect of alfalfa on the yield and quality of forage oat. J Agric Sci. 2020;12(3): 39-47.
100. Zhi X, Li F, Li L, Li H, Li S, Sun Y. Effect of different fertilization levels on yield and benefit-cost ratio of oat in Hulunbuir of Inner Mongolia, China. Sci Agric Sin. 2019; 52(7): 1369-82.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/99016