RESPONSE OF OAT GENOTYPES TO SEED RATE AND NITROGEN LEVELS ON FORAGE YIELD AND QUALITY UNDER IRRIGATION

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1. INTRODUCTION

Forages are the main stay of animal wealth and their production is the backbone of livestock industry. The scarcity of green forages and grazing resources in the country has made the livestock to suffer continuously with malnutrition resulting in their production potentiality at sub optimum level as compared to other countries.

India is having the largest livestock population of 520 million heads, which is about 15 per cent of the world's livestock population. India supports 55 per cent of world's buffaloes, 16 per cent of the world's cattle, 20 per cent of the world's goats and 4 per cent of the world's sheep population. But, the country is having only 4.4 per cent of the cultivated area under fodder crops with an annual total forage production of 833 m t (390 m t green and 443 m t dry forage). Whereas, the annual forage requirement is 1594 m t (1025 m t green and 569 m t dry) to support the existing livestock population. The present feed and fodder resources of the country can meet only 48 per cent of the requirement, with a vast deficit of 61.1 per cent and 21.9 per cent of green and dry fodder, respectively (Anonymous, 2009).

The farmers possessing the livestock breeds with higher milk yield potential are suffering from deficit in green and dry fodder availability in the country. To overcome this deficit, dairy farmers resort to the increased use of costly concentrate feeds, which increases the cost of production. It is pertinent to note that out of the total cost of milk production, the feed cost alone accounts to 65 to 70 per cent.

Karnataka supports 28.55 million heads of livestock with only 3.5 per cent of the cultivated area under fodder crops. The annual fodder requirement in the state is 122 m t of green forage and 24 m t of dry fodder with the production of 85 and 15 m t of green and dry fodder, respectively, with a deficit of 46 m t of total fodder (Anonymous, 1999).

Although the total milk production in India (90 m t) is highest in the world, the productivity per animal is far below compared to the developed countries, which is due to the supply of inadequate quantity of quality fodder. In India, due to increased population pressure and competing demand for food crops, it is not possible to increase the area under fodder crops. The only way to bridge the large gap between supply and demand of fodder is to maximize the fodder production per unit area and unit time within the existing farming systems and utilizing marginal, sub marginal dry lands and problematic soils for developing feed and fodder resources. Simultaneous efforts in the genetic upgradation of the livestock as well as identification and introduction of new high yielding nutritious fodder crops and with agronomic practices for their welfare are the need of the day.

Fodder oat (*Avena sativa* L.) are presently grown in temperate parts of the world including USA, Canada, Europe *etc.* as spring-sown cultivars. In the tropical countries and at higher altitude regions, it is grown as a winter annual. Oat ranks sixth in the world cereal area, production and productivity, followed by wheat, maize, rice, barley and sorghum. Oat is the most important cereal fodder crop grown in the winter season in the north western and central India and now extending to the eastern regions. Oat requires a long and cool season for its growth. Therefore; it is successfully grown in the plains and hilly areas of the country. In India it is cultivated on about 5 lakh ha area. Fodder oat is a fast growing, high tonnage crop and require a large quantity of fertilizers. In India it is being grown in Punjab, Haryana, Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh, Madhya Pradesh, Rajasthan, Maharashtra and West Bengal. The genus *Avena* comprises about seventy species of which a few are cultivated. *A. sativa* and *A. byzantina* are the main oats grown for fodder and grain purposes.

In Karnataka, animals are mainly fed with crop residues of paddy, sorghum, bajra, maize, wheat, ragi, groundnut, chickpea *etc.* and only few dairy farmers grow cultivated forages like Napier bajra hybrids and maize which provide forage in *kharif* and summer seasons. Thus, to alleviate the acute shortage of green fodder during the lean period of winter season oat is an important winter cereal fodder crop during *rabi*, which is rich in protein, energy, vitamin B_1, phosphorus and iron (Pradhan and Mishra, 1994).

Oat has wider adaptability because of its excellent growing habits, quick regrowth, better yield potential and provides palatable, succulent and nutritious green fodder (Singh et al., 1989). Thus, there is a need to explore its potential in Karnataka particularly in northern Karnataka where winter temperatures are low and appear congenial for its growth.

The rate of seeding and nitrogen fertilization, because of their influence on growth and development play a vital role in increasing the herbage yield of cereal based forages. The work on suitability of genotypes, seed rate and nitrogen levels in oat is lacking in this region.

Keeping the above points in view, the present investigation was planned to study the response of oat genotypes to seed rate and nitrogen levels on forage yield and quality under irrigation during *rabi* 2010-11 with the following objectives.

1. To find out suitable genotype, optimum seed rate and nitrogen level for higher forage production and superior forage quality of oat.
2. To study the economics of forage oat cultivation.

2. REVIEW OF LITERATURE

Forage plays an important role in milk production. The shortage of adequate quantity of quality forage is one of the important factors responsible for lower production of milk. Few dairy farmers grow cultivated forages like Napier-bajra hybrid and maize which provide forages in *kharif* and summer seasons and practically there is paucity of green forage in winter season. In this context, literature pertaining to oat genotype, seed requirement and nitrogen are reviewed in this chapter.

2.1 Performance of genotypes

Genotypes play an important role in crop production and the potential yield of a genotype within the genetic limit is determined by environment. The release of high yielding varieties has contributed a great deal towards the improvement of yield. The yield potential can be further exploited through better agronomic practices. Performance of oat genotypes with respect to growth, yield and fodder quality is reviewed here.

2.1.1 Growth parameters

2.1.1.1 Plant height

Bhal *et al.* (1987) found that plant height as an important character in oat and identified K-10, OS-7, UPO-160 and Kent as promising genotypes. Joshi and Singh (1982) at Pantnagar observed a range of plant height varying from 19 to 57 cm at 55 days after sowing among twelve oat genotypes. They also observed higher plant height in Kent. Deorari (2002) at Pantnagar recorded higher plant height in UPO-212 over UPO-271 and UPO-267 at 60 days after sowing, and thereafter, UPO-271 attained maximum plant height. Bali *et al.* (1998) at Srinagar noticed higher plant height of SK-7 followed by Kent compared to five other genotypes. Reddy and Rai (1977) found significant difference among eight genotypes of oat at maturity. Singh and Mishra *et al.* (1993) observed moderate variability of plant height in oat, while Joshi *et al.* (1997) noticed same plant height of 135 cm in Kent and JHO-822.

Srivastava and Singh (1996) did not observe any significant difference between Kent and JHO-851 with regard to plant height in Faizabad (U.P.). Rao *et al.* (1978) reported that taller plants in late genotypes compared to that of medium duration, which in turn excelled early maturing genotypes at Jhansi. Reddy (1976) from Pantnagar also indicated that plant of early variety attained a height of 36 cm at 30 days after sowing, and thereafter, increased with maturity. Jain (1994) and Trivedi (1995) also reported similar trend of increase in plant height with crop age.

2.1.1.2 Number of shoots

Joshi and Singh (1982) at Pantnagar documented maximum number of shoots per meter row length in Coker 72-34 oat genotype followed by UPO-123, UPO-92 and UPO-98 at 55 days after sowing and in UPO-121 and UPO-123 at 50 per cent heading stage. Bali *et al.* (1998), at Srinagar, found significantly more number of shoots in SK-0-7 followed by Kent. Taneja *et al.* (1981) from Hisar reported higher number of shoots in HFO-114 than in Kent. Singh *et al.* (1998) observed large variations in varieties and reported maximum number of shoots per unit area in UPO-92 among the varieties studied. Habib *et al.* (2003) did not observe statistically significant difference in number of tillers per plant among ten elite genotypes. Joshi *et al.* (1996) reported significantly more number of shoots in UPO-234 than UPO-212. Rao *et al.* (1978) at Jhansi observed more number of tillers at tillering stage in late erect type, and in early medium genotypes. They also indicated maximum number of tillers at tillering stage than at both booting and flowering stages in drooping and spreading type oat.

2.1.1.3 Dry matter accumulation

Joshi (1980) reported that dry matter accumulation in stem and leaves increased with crop age except a shortfall just after first cut. He observed more dry matter accumulation in Coker 72-34, UP-94 and UPO-130 in comparison to UPO-137 and UPO-92. Jain (1994) reported maximum leaf dry matter accumulation in UPO-94 than others. Chandra (2000) observed maximum stem dry matter accumulation in UPO-212 followed by UPO-253 and UPO-240. Reddy (1976) indicated that dry matter accumulation through leaves increased at a faster rate upto 70 days after sowing, and thereafter reached peak at 110 days after sowing in almost all varieties studied except in Rapida and Indio at Pantnagar. He also indicated that dry matter accumulation in stem increased continuously with advancement of crop age. Moreover, he noticed more dry matter accumulation in long duration varieties than in short duration varieties. Singh (1992) observed that dry matter accumulation in whole plant as well as its distribution through leaf and stem increased with crop age except a shortfall at harvest in case of leaf dry matter. He also reported maximum dry matter accumulation through leaves in Kent upto 30 days after sowing followed by, UPO-94. Bhal *et al.* (1987) noticed significant difference in leaf to stem ratio among thirty genotypes of oat.

2.1.2 Forage yield

In oat, forage yield was found positively correlated with plant height, stem girth, number of tillers, number of leaves, leaf length and leaf breadth as well as days to 50 per cent flowering (Tyagi *et al.*, 1979 and Patel and Bedis, 1994). Rao *et al.* (1978) reported positive association of fodder yield at heading with that of pre-flowering leaf area, leaf weight and height in erect genotypes, with height in spreading genotypes, and with leaf weight and specific leaf weight in drooping genotypes. Bahl *et al.* (1988) indicated that green fodder yield in oat was positively correlated with stem thickness and leaves per plant at Jabalpur. Yang *et al.* (1989) from Korea reported 11 tonnes dry matter yield of which 3.75 tonnes was leaves, 5.31 tonnes was culm and 1.94 tonnes was panicle from a hectare of oat field harvested at heading stage.

Based on observations recorded on a range of environment, Collins *et al.* (1990) from USA concluded that early heading cultivars generally gave lower yield than late heading cultivars. Chapoko *et al.* (1991) from Argentina after thorough evaluation of 64 elite genotypes, concluded that late heading genotypes typically had high forage yields than early heading genotypes. Koller (1994) working for three consecutive years on 36, 25, and 16 genotypes also concluded that dry matter yield was significantly correlated with late maturity. Hussain *et al.* (1994) also reported similar finding from Pakistan.

Kim *et al.* (1999) from Korean Republic in spring sown oat noticed that early heading varieties (50 days after sowing) gave more green and dry matter yields than late heading (77 days after sowing) varieties. Similarly, Prakash and Verma (1995) also reported that the green fodder yield of oat was significantly higher ($P<0.01$) at flowering stage (872 q/ha) than at pre flowering (639 q/ha) or post-flowering stage (686 q/ha). Whereas, dry matter yield was significantly higher ($P<0.01$) at post flowering stage (210 q/ha).

Dhumale and Mishra (1979) reported positive association of fresh yield with plant height and flag leaf width in 49 varieties. Prasad and Mukherji (1998) observed that herbage yield in general, increased with delay in harvesting. Hasan *et al.* (1995), working with seven oat varieties, under Jammu and Kashmir condition observed green and dry matter yields of 415 to 547 and 88 to 103 q per ha, respectively. Reddy and Rai (1977) at Pantnagar observed dry matter yields of nine oat varieties between 131 and 275 q per ha. They further indicated that variety Kent recorded the highest dry matter yield than others.

Habib *et al.* (2003) from Pakistan working on ten oat genotypes found that green and dry fodder yields of oat varied between 67 to 101 and 9 to 13 tonnes per hectare, respectively. Prakash *et al.* (1997) from three years experiment on nine genotypes observed significant variation in both green and dry matter yields. Babalad *et al.* (1993) working with four genotypes reported significantly higher green fodder yields of 18, 16, and 16 t per ha in JHO-829, Kent, and JHO-817, respectively. Kumar (1998) from Rajasthan observed significantly higher total green and dry matter yields in UPO-240 compared to Kent. Singh (1992) at Pantnagar obtained highest green forage and dry matter yields from UPO-212 and JHO-822. At Faizabad, variety Kent out yielded other varieties both in green and dry matter yields (Srivastava and Singh, 1996). Chandra (2000) at Pantnagar found maximum green forage yield, dry matter yield and dry matter content in UPO-212 followed by UPO-253 and UPO-240.

2.2 Effect of seed rate

2.2.1 Growth parameters

Singh *et al.* (1979) reported significant increase in number of shoots per meter row length upto 100 kg seeds per ha, beyond 100 kg the results were non-significant with four genotypes at three sowing dates.

Singh *et al.* (1989) observed non-significant difference for plant height among different seed rates, where as number of shoots per meter row was higher at 125 kg seeds per ha as compared to 100 kg seeds per ha with two sowing methods at four nitrogen levels. Sowing rate did not affect plant height and date of milk stage (Droushiotis, 1990). The percentage seedling emergence was 93.4, 71.4 and 70.6 with 120, 160 and 200 kg seed per ha, respectively and number of tillers per plant and leaf width decreased with increasing sowing rate (Han and Kim, 1992).

2.2.2 Forage yield

Younie (1976) reported that the sowing rate had no significant effect on dry matter yield but 150 kg per ha sowing rate was found adequate. Singh *et al.* (1979) reported that increasing seed rate from 50 to 75 kg per ha resulted in higher green forage as well as dry matter yield, but such differences were statistically non-significant during 1976 and 1977. Similarly, higher seed rates (100 and 125 kg/ha) did not bring any improvement in the forage yield over 75 kg per ha during both the years with four genotypes at three sowing dates.

Uhliar (1979) observed that the average yield of dry matter was not affected by sowing rate and suggested to reduce the seed rate from 4.0-4.5 million seeds per ha (recommended) to 60-80 kg per ha. Veera Raghavaiah *et al.* (1979) reported that for two years, the fodder yield was not affected by seed rate and 50 kg per ha seed rate gave equal fodder yield as 100 kg per ha with four nitrogen levels (0, 40, 80 and 120 kg/ha).

Lowe *et al.* (1980) reported that dry matter yield did not increase beyond 45 kg per ha seed rate although higher seed rates did increase the yield at initial defoliation. Singh *et al.* (1989) observed significantly higher green forage and dry matter yield with 125 kg per ha seed rate as compared to 100 kg per ha when tried with two sowing methods at four nitrogen levels (0, 50, 100 and 150 kg per ha).

The sowing rate did not affect the dry matter yield. Whereas, 14 percent dry matter was increased when harvesting was delayed from booting to 50 per cent heading (Droushiotis, 1990). Khan *et al.* (1993) observed increase in dry matter with increasing sowing rates upto 500 kg per ha at early harvests while later in the season there was no significant difference between the two highest sowing rates (100 and 500 kg/ha). The green forage and dry forage yields were not much affected by sowing rates of 40, 60, 80, 100 or 120 kg seed per ha. Whereas, higher green forage yield was obtained with 120 kg seed per ha (Jan and Jan, 1994).

2.2.3 Forage quality

Uhliar (1979) observed that the total N was not affected by sowing rate, whereas yields of phosphorus, calcium, nitrogen free extract and starch were little affected by sowing rate. Veera Raghavaiah *et al.* (1979) observed highest crude protein percentage (10.15) with 50 kg per ha seed rate which was reduced at higher seed rate with four nitrogen levels. Lowe *et al.* (1980) observed that the nitrogen yields of oats did not differ with sowing rate.

Sowing rate did not affect protein content and digestibility where as digestibility percentage decreased with delaying in harvest and was 63.6, 58.2 and 54.2 per cent at boot, 50 per cent heading and at milky stages, respectively (Droushiotis, 1990).

Crude protein content increased upto 100 kg seed per ha, further increase in seed rate beyond 100 kg decreased the crude protein content (Khan *et al.* 1993).

2.2.4 Economics

Veera Raghavaiah *et al.* (1979) reported that the average net income was highest in 75 kg per ha seed rate (Rs. 2873/ha) but this gave only Rs. 45 per ha extra over 50 kg per ha where as 100 kg and 125 kg per ha seed rate recorded lower net income i.e. Rs. 2737 and Rs. 2613 per hectare, respectively at four nitrogen levels (0, 40, 80 and 120 kg /ha).

2.3 Effect of nitrogen levels

Nitrogen is an essential part of protein and is a constituent of physiologically important compounds like nucleotides, phosphatides, vitamins, enzymes and hormones that promote growth and development in crop plants. It is the most frequently deficient nutrient in soils and hence nitrogen input is required in most non-legume crop production system (Havlin *et al.,* 1999). According to Das *et al.* (1995), the efficiency with which the applied nitrogen is utilized in production of targeted yield, vanes with environmental condition and the crop itself. Attempts are made here to present available findings on the effect of nitrogen on performance of forage oat.

2.3.1 Growth parameters

2.3.1.1 Plant height

Chaturvedi (1981) at Pantnagar observed that increasing the level of nitrogen from 0 to 160 kg per ha significantly increased plant height upto 70 days after sowing. Singh *et al.* (1973) reported that increased application of nitrogen increased average internodal length, number of internodes, culm length and thereafter, plant height. Taneja *et al.* (1981) from Hisar reported increased plant height due to increased nitrogen dose with better response at 120 kg N per ha. Chakraborty *et al.* (1999), working under West Bengal condition, observed maximum plant height of 42.9 cm at 30 days after sowing and 117 cm at 90 days after sowing with application of 120 kg N per ha. Singh (1992) noticed significantly superior plant height with increased dose of nitrogen upto 160 kg per ha. Sangha *et al.* (1980) from Ludhiana reported that increased application of nitrogen from 0 to 80 kg per ha increased the plant height and thereby forage yield. Singh *et al.* (1997) also reported that plant height, increased to the maximum of 118.9 cm with increased application of nitrogen upto 150 kg per ha. Pradhan and Mishra (1994) from Orissa recorded highest plant height of 75.9 cm in plots assigned to 120 kg N per ha. Bokde (1968) concluded that plant height in general, increased with successive level of nitrogen upto the highest dose compared to all other forage yield attributes.

2.3.1.2 Number of shoots

Bali *et al.* (1998) recorded more number of shoots at 150 kg N per ha over that of 50 and 100 kg N per ha. Chaturvedi (1981) at Pantnagar observed that enhancing level of nitrogen from 0 to 160 kg per ha caused for increased number of shoots significantly between 70 and 115 days after sowing. Chakraborty *et al.* (1999) reported maximum number of tillers per meter square area with nitrogen at 160 kg per ha. Singh (1992) indicated that number of shoots increased with increased level of nitrogen at all growth stages. Pradhan and Mishra (1994) from Orissa recorded more number of shoots at 120 kg N per ha than 80 Kg N per ha. Joshi *et al.* (1996) reported that number of shoots increased with nitrogen upto 120 kg per ha and significantly reduced at 160 kg N per ha.

2.3.1.3 Dry matter accumulation and leaf to stem ratio

Chakraborty *et al.* (1999) noticed more dry matter accumulation in leaves, shoots and whole plants with nitrogen. He also noticed decreased tendency in leaf to shoot ratio. Joon *et al.* (1988) observed similar trend of increased dry matter accumulation with successive level of nitrogen upto 160 kg per ha. Sharma *et al.* (2001) noticed significantly higher leaf to stem ratio (10.22) with application of nitrogen at the rate of 80 kg per ha compared to 7.1 and 8.2 obtained with 40 and 60 kg N per ha, respectively.

2.3.2 Forage yield

Barik and Roy (2002) from West Bengal reported that nitrogen applied at the rate of 60 kg per ha resulted in significantly higher green and dry forage yields than 40 kg N per ha. Thakuria and Gogoi (2001) from experiment conducted with three levels of nitrogen (0, 40 and 80 kg per ha) reported significant increment in green forage yield upto 80 kg N per ha and dry matter yields upto 40 kg N per ha and the average increment in yield was 13.9 per cent for green forage and 10.8 per cent for dry matter yields. Sharma and Bhunia (2001) from Rajasthan documented significantly increased forage yields with increased nitrogen only upto 80 kg N per ha. Pradhan and Mohapatra (1995) from Orissa found highest yields of green and dry matter with application of nitrogen at the rate of 120 kg per ha. Singh *et al.* (1999) from Faizabad (Uttara Pradesh) also reported similar findings.

Mannikar *et al.* (1974) at Jhansi observed an average yields of 47.7 and 54.5 t fresh fodder and 8.2 and 8.8 t dry matter per ha with application of nitrogen at the rate of 90 and 120 kg per ha, respectively. Bali *et al.* (1998) from Kashmir revealed markedly increased green and dry forage yields with successive level of nitrogen from 0 to 150 kg per ha. They found that the mean green forage yield increased by 31.9 per cent and dry matter yield by 9.6 per cent with each increased level of nitrogen between 50 and 100 kg per ha over the control. Hasan *et al.* (2000) from Srinagar also investigated significant increase in green and dry matter yields with increased application of nitrogen upto 160 kg per ha. Singh *et al.* (1973) from Himachal Pradesh also reported that the fresh and dry matter yields of oat increased from 35.6 and 7.8 t per ha (control) to 49.1 and 11.0 t per ha, respectively with 120 kg N per ha.

Gonet (1975) reported an average yield of 40.2 t per ha for nitrogen applied at the rate of 60-300 kg per ha. Dalwadi *et al.* (1987) also reported that increasing the level of nitrogen from 60 to 90 and 120 kg per ha increased average dry matter yields from 9.5 to 10 and 11.5 t per ha, respectively. Shukla *et al.* (1998) reported that the green and dry matter yields of Kent increased with increased nitrogen from 40-120 kg per ha. They observed maximum yield of 40.4 t per ha from application of 120 kg N per ha. Patel and Vihol (1990) from Gujarat also reported 65.3 t green fodder and 10.2 t dry matter yields with increased application of nitrogen upto 160 kg per ha.

Shukla and Lal (1994) at Jhansi observed mean green forage yield of 30.2 t per ha from application 75 kg N per ha. Singh *et al.* (1998) at Palampur observed significantly higher green fodder and dry matter yields only upto 80 kg N per ha. Further increase in nitrogen upto 120 kg per ha did not show appreciable improvement in yield.

Sharma *et al.* (2001) reported that the green forage yields of Kent increased significantly to 159 q per ha during the first year and 170 q per ha during the second year with increased application of nitrogen upto to 80 kg per ha. A two year study of Midha *et al.* (1999) also revealed that the average green forage yield of oat increased significantly from 95.5 to 210.45 q per ha and dry matter yields from 17.0 to 56.5 q per ha with increase in nitrogen upto 70 and 80 kg per ha, respectively. Application of 80 kg N per ha however, resulted in a sharp decline in green forage yield (260.9 q/ha).

The work of Reddy and Tomer (1988) at Karnal showed that dry matter yield of oat increased significantly to 91.1 q per ha with increased application of nitrogen upto 120 kg per ha. Similar observations were reported by Bali *et al.* (1998) from Kashmir, where application of nitrogen at the rate of 150 kg per ha resulted in green herbage yields of 450.8 q per ha as against 366.4 and 441 q per ha under 50 and 100 kg N per ha, respectively.

Suhrawardy and Kalita (2001) concluded that increased application of nitrogen upto 80 kg per ha significantly increased both green and dry matter yields of Kent genotype. The green forage yield increased upto 154.2 q per ha and the dry matter yields upto 43.7 q per ha.

Tripati and Hazra (1994) at Jhansi found significantly increased dry matter yield upto 101.6 q per ha with enhanced nitrogen level upto 80 kg per ha. Gill and Malik (1983) from Haryana also noticed increased green (359.3 q/ha) and dry matter (68.4 q/ha) yields with increased application of nitrogen over the control (188.7 q per ha green and 54.7 q per ha dry matter yields). Singh *et al.* (1984) at Haryana also observed that the green and dry matter yields of HFO-114 increased by 45.8 and 81.0 per cent over the control with application of 120 kg N per ha.

Dubey *et al.* (1995) from Jabalpur reported that the average green and dry matter yields of Kent and Brunker genotypes increased significantly to 446 q per ha and 75 q per ha respectively with application of 150 kg N per ha compared to 117 q per ha green and 23 q per ha dry matter yields. Pradhan and Mishra (1994) from Orissa reported that green and dry matter yields of Kent increased to 300 and 60 q per ha, respectively with increased nitrogen upto 120 kg per ha. Singh *et al.* (2000) reported 55.5, 85.5 and 105.6 per cent increment in green forage yields with each application of nitrogen at the rate of 30, 60 and 90 kg per ha, respectively. Kumar *et al.* (1997) from a two years study also reported that green and dry matter yields increased by 520 and 121.87 q per ha, respectively with the application of nitrogen at the rate of 120 kg per ha. Dhaliwal *et al.* (1984) under Ludhiana conditions reported increased herbage yields with application of nitrogen upto 80 to 120 kg per ha.

2.3.3 Forage quality

2.3.3.1 Crude protein

Chaturvedi (1981) observed that the percentage of nitrogen in plant tissue declined with progressive stage of growth and increased with increased level of nitrogen upto 160 kg per ha. Das *et al.* (1974) from Hisar also reported that the crude protein content of oat increased from 5.9 to 10.9 per cent with increased application of nitrogen (0-120 kg per ha). Sharma *et al.* (2001) from Gujarat recorded significantly higher nitrogen and crude protein contents due to application of 100 kg N per ha. Givens *et al.* (2004) from UK reported that increased dose of nitrogen upto the optimum level resulted in consistent and significant increase in crude protein content from 95 to 118 q per ha of dry matter for all varieties studied at various sites. Kumar (1998) observed crude protein content of 10.3 per cent with increased application of nitrogen upto 120 kg per ha. He also indicated that the crude protein yield increased from 36.8 (control) to 39.7 q per ha. Thakuria (1992) from Assam found positive improvement in crude protein yield from 317.6 q per ha (control) to 609.1 q per ha with increased application of nitrogen upto 100 kg per ha. Kakol *et al.* (2003) found that crude protein content of oat plant increased with increased application of nitrogen upto 150 kg per ha. Singh *et al.* (1997) at Shalimar found crude protein content of 7.2, 8.8, 10.3 and 10.9 per cent with each application of 0, 50, 100 and 150 kg N per ha, respectively. Pradhan and Mishra (1994) from Orissa reported crude protein yield of 6.55 q per ha with application of nitrogen at the rate of 120 kg per ha. Sheoran *et al.* (1998) from Haryana obtained crude protein content and yield of 7.3 per cent and 3.96 q per ha with application of 40 kg N per ha. Bali *et al.* (1998) reported maximum crude protein content of 9.7 per cent and crude protein yield of 9 q per ha with increased application of nitrogen up to 150 kg per ha. Reddy and Tomer (1988) from Karnal reported that application of 120 kg N per ha resulted in maximum crude protein content of 9.5 per cent. Pate1 and Rajagopal (2002) at Chattisgarh reported crude protein yield of 10.6 q per ha from application of nitrogen at 75 kg per ha.

2.3.3.2 Crude fibre

Kakol *et al.* (2003) reported increased crude fibre content with nitrogen upto 100 kg per ha at 55 days after sowing and up to 125 kg per ha at 50 per cent flowering stage. Naveen and Sood (1995) from Palampur (Himachal Pradesh) reported that the crude fibre content increased with increased application of nitrogen upto 60 kg per ha. Mandal *et al.* (2000) also reported that fertilizer nitrogen above 40 kg per ha increased the crude fibre content. Contrary to this, Reddy and Tomer (1988) from Karnal reported that each increased dose of nitrogen (0-100 kg per ha) reduced crude fibre content from 30.7 to 27.5 per cent during first year and 34.7 to 31 per cent during the second year.

2.3.4 Economics

Bokde (1968) reported that net income and net profits increased with increased level of nitrogen and the highest profit of Rs. 1164 per ha was observed at 100.9 kg N application. Veera Ragavaiah *et al.* (1979) recorded highest average net income of Rs. 3041 per ha with application of 80 kg N per ha along with two sowing methods at four seed rates.

Taneja *et al.* (1981) reported that the application of N increased the net profit with the successive increase in the dose of N upto 120 kg per ha (Rs. 4160 / ha) but magnitude of increase between 80 and 120 kg N per ha was marginal. Reddy and Tomer (1985) observed highest net income of Rs. 8291 per ha with application of N at 120 kg per ha along with phosphorus levels.

Gross returns increased with increased N levels from 0 to 120 kg N per ha and the highest gross return of Rs. 4867 per ha was obtained with 120 kg N per ha when the crop was harvested for fodder under different irrigation levels (Reddy and Hussain, 1990). Similarly, Patel and Patel (1991) recorded highest net returns with 80 kg N per ha. Das *et al*. (1995) observed increased net returns and benefit cost ratio with increased level of N in oat cut once after 45 days after sowing (DAS) for fodder than no cut for fodder.

The comparative economics worked out by Pradhan and Mishra (1994) in oat indicated that the net profit was negative in no nitrogen (control) but increased progressively with the increased level of N and the highest net profit of Rs. 2428 per ha was recorded from application of N @ 120 kg per ha. Net returns per ha increased with the increasing levels of N and application of N @ 120 kg per ha resulted in maximum net returns of Rs. 11,128 per ha (Singh *et al.,* 1998).

2.4 Interaction effect

Uhliar (1979) observed higher forage yields at sowing rate of 60-80 kg seed per ha with application of 60-80 kg N per ha than recommended plant density of 4.0-4.5 million seeds per ha with application of 100-120 kg N per ha. Veera Raghavaiah *et al.,* (1979) reported that the interaction between seed rate and nitrogen level was not significant with regard to green fodder yield for two years.

Ulmann (1989) reported that the maximum dry matter yield (5.92 t/ha) was obtained with the lowest sowing rate (3.5 million seeds per ha) and application of highest level of nitrogen (120 kg N/ha) during 1985, it was 6.16 t per ha at the lowest sowing rate and N rate (60 kg / ha) during 1986 and the highest dry matter yield of 6.64 t per ha at the highest sowing rate (5.5 million seeds per ha) and highest N level during 1987.

Han and Kim (1992) reported a sowing rate of 200 kg per ha along with 100 kg N per ha was recommended for autumn oats production for fresh cut forage in the Korean Republic.

2.5 Nitrogen uptake

According to Hopkins *et al.* (1994) efficient use of grass in intensive production system is dependent upon adequate concentration of mineral elements in the herbage. Oat plant removes more nitrogen from the soil. Bhagwati *et al.* (1989) at Hisar observed more nitrogen uptake by wild oat than by wheat plant.

Increased application of nitrogen increased the availability of nitrogen in soil (Chakraborty *et al*., 1999). The nitrogen uptake of the crop also increased with increased application of fertilizer nitrogen (Hazra and Tripathi, 1986 and Collins *et al*., 1990). Kirikham and Wilkins (1994) noticed consistently higher concentration of nitrogen in plants harvested from plots assigned to the highest dose of nitrogen. Tripathi (1994) at Jhansi observed significantly higher nitrogen uptake with application of nitrogen upto 120 kg per ha in soils with low fertility and upto 80 kg N per ha in soils with medium to high NPK. Peschke *et al.* (1981) also indicated that the ratio of soil to fertilizer nitrogen uptake by the crop increased from 3:1 when 50 kg N per ha was applied to 1:1 with 200 kg N per ha. Trofymow *et al.* (1987) observed more depletion of nitrogen from the soil in oat field. Chaturvedi (1981) recognized that total nitrogen .uptake increased significantly with increase in applied nitrogen upto 120 kg per ha.

Glazewski *et al.* (1975) observed high amount of nitrogen uptake by oat crop from emergence to earhead formation stage than that of later stages, despite large quantity of available nitrogen in the soil. They further ascertained that the nitrogen released during aging of vegetative organs as the sole source of nitrogen for the developing grain in oat. Verma (1984) from Pantnagar reported that the nitrogen content in plant tissue decreased with crop age. Peterson (1988) found highest protein content in leaves of oat plant than in internodes and rachis. Pederson *et al.* (2002) observed more concentration of nitrogen in flowers closely followed by leaves and less concentration in stems and roots of oat plant.

3. MATERIAL AND METHODS

Details of the materials used and the techniques adopted during the course of investigation are presented in this chapter.

3.1 Location

The field experiment was conducted at Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad under irrigated conditions during *rabi* 2010-11 in plot No. 75 of C block. Dharwad is located in Northern Transition Zone (Zone 8) of Karnataka and is situated at 15°26' North latitude, 75°07' East longitude and at an altitude of 678 m above mean sea level (MSL).

3.2 Soil characteristics

The soil of the experimental site was clay. Composite soil samples were collected from 0-30 cm depth before the initiation of the experiment. Soil samples were air dried, powdered and allowed to pass through 2 mm sieve and were analysed for physical and chemical properties (Table 1). The soil was having normal pH with low available nitrogen, medium available phosphorus and high available potassium.

3.3 Climate and weather conditions

3.3.1 Climate

The Northern transition zone (Zone - 8) of Karnataka state receives the rainfall from both Southwest and Northeast monsoons, which is well distributed from June to November.

3.3.2 Weather during the experimental year

The monthly mean data on climatic parameters viz., rainfall, air temperature and relative humidity as recorded at meteorological observatory, MARS Dharwad, during the experimental year 2010-11 and the mean of previous 60 (1950-2009) years are furnished in Table 2 and depicted in Fig. 1.

3.3.3 Weather during the crop growth period

Compared to normal, the rainfall received did not vary much during the crop growth period.

3.4 Previous crop grown on the experimental area

During *kharif* 2010, fodder maize (cv. African tall) was grown with recommended cultivation practices for fodder purpose.

3.5 Experimental details

3.5.1 Treatments

There were 18 treatment combinations consisting of two oat genotypes, three seed rates and three nitrogen levels. The treatment details are:

I - Genotype

1. OS-6 (G-1)
2. JHO-822(G-2)

II - Seed rate (kg ha^{-1})

1. 75 (S_{75})
2. 100 (S_{100})
3. 125 (S_{125})

Table 1: Physical and chemical properties of the soil of the experimental field

Sl. No.	Particulars	Value	Remarks	Method employed	Reference
I.	**Physical properties**				
A	Particle size distribution (%)			Hydrometer method	Piper (1996)
1.	Coarse sand	5.30			
2.	Fine sand	9.78			
3.	Silt	29.32			
4.	Clay	55.60			
B	Textural class		Clay	International society of soil science system	ISSS (2002)
C	Bulk density (Mgm^{-3})	1.27		Core sampler method	Dastane (1967)
II	**Chemical properties**				
1	pH(1:2.5 soil : water solution)	8.02	Normal	Buckman's pH meter	Piper (1996)
2	Electrical conductivity ($dS\ m^{-1}$)	0.31	Normal	Conductivity bridge (Syntronics model-304)	Jackson (1967)
3	Available nitrogen ($kg\ N\ ha^{-1}$)	210.48	Low	Alkaline permanganate method	Subbiah and Asija (1956)
4	Available phosphorus ($kg\ P_2O_5\ ha^{-1}$)	38.67	Medium	Olsen's method	Sparks (1996)
5	Available potassium ($kg\ K_2O\ ha^{-1}$)	456.81	High	Flame photometric method	Sparks (1996)

Table 2: Monthly meteorological data for the experimental year (2010-11) and the mean of past 60 years (1950-2009) of the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad

Month	Rainfall (mm)		Mean air temperature (^{0} C)				Relative humidity (%)	
			Maximum		Minimum			
	2010-11	1950-2009	2010-11	1950-2009	2010-11	1950-2009	2010-11	1950-2009
2010								
May	63.1	80.4	34.4	33.7	22.4	21.30	63	66.5
June	63.4	114.7	28.7	28.8	21.8	22.37	75	81.0
July	155.0	154.1	28.6	29.0	20.8	21.00	84	87.1
August	190.7	98.0	26.9	26.9	20.7	20.01	84	85.9
September	164.9	107.0	28.1	28.5	20.2	19.91	83	82.1
October	177.0	127.1	30.1	30.4	19.5	18.41	77	75.6
November	92.8	33.2	29.6	30.1	19.0	15.94	79	68.0
December	0.6	6.4	28.9	29.2	14.1	12.55	65	63.2
2011								
January	0.0	0.1	29.2	29.5	12.5	14.58	59	63.1
February	21.6	1.0	30.8	31.2	14.0	16.32	48	51.4
March	0.8	2.2	35.2	32.4	18.6	19.51	44	55.8
April	77.4	50.2	34.9	37.3	20.2	18.80	57	75.6
Total	**944.2**	**774.4**	-	-	-	-	-	-

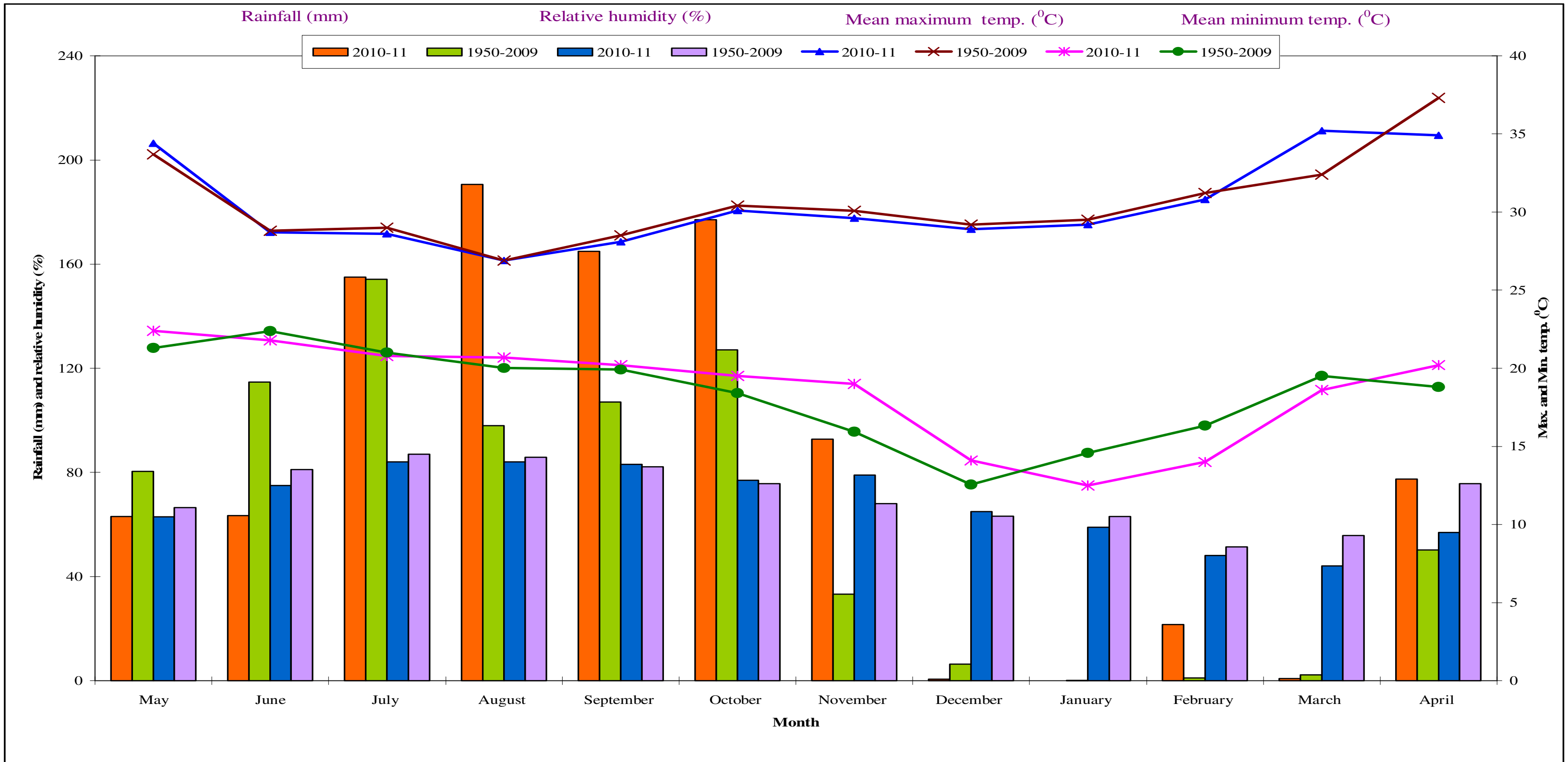


Fig. 1. Monthly meteorological data for the experimental year (2010-11) and the mean of the past 60 years (1950-2009) of the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad

Fig. 1. Monthly meteorological data for the experimental year (2010-11) and the mean of the past 60 years (1950-2009) of the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad

III - Nitrogen levels (kg ha^{-1})

1. 90 (N_{90})
2. 120 (N_{120})
3. 150 (N_{150})

3.5.2 Design and plan of layout

The experiment was laid out in RBD design with three replications. The plan of layout is illustrated in Fig. 2 and general view of the experimental plot is depicted in Plate 1.

3.5.3 Plot size

Gross : 4.0 m × 3.0 m = 12.00 m^2

Net : 3.4 m x 2.4 m = 8.16 m^2

3.5.4 Manures and fertilizers

The FYM @ 7.5 t ha^{-1} and nitrogen as per treatments along with 60:40 kg P_2O_5 and K_2O ha^{-1} was applied.

3.6 Cultural operations

3.6.1 Land preparation

The land was prepared by using tractor drawn cultivator once and bullock drawn harrow once. The smoothened land was laid out according to the experimental plan.

3.6.2 Fertilizer application

The crop was supplied with well decomposed FYM prior to experimentation and the nitrogen, phosphorus and potassium were applied in the form of urea, diammonium phosphate and muriate of potash. The nitrogen was applied as per treatment specifications. Half the dose of nitrogen and full dose of phosphorus and potassium were applied at the time of sowing in band in small furrows opened manually adjacent to the seed line and covered with soil to avoid the losses, remaining 25 per cent nitrogen was applied at 25 DAS and rest 25 per cent was applied after first harvest.

3.6.3 Seeds and sowing

The seeds of oat genotypes were obtained from Indian Grassland and Fodder Research Institute, Regional Research Station, Dharwad (cv. JHO-822) and from AICRP on Forage Crops, Mandya (cv. OS-6), University of Agricultural Sciences, Bangalore.

The seed rate was used as per the treatments. The seed lines were opened manually at 30 cm apart and seeds were sown in the rows and covered.

3.6.3.1 Salient features of the genotypes used (Plate 2)

JHO-822 - A multicut variety developed from a cross between IGO-4268 x Indio-6-5-1. It was released in 1989 from Indian Grassland and Fodder Research Institute, Jhansi for cultivation for whole of India (multicut). It takes 95-100 days to flower and 125-130 days for maturity.

OS-6 - It is a cold and drought tolerant variety and provides green fodder during the lean period (December and January months) when green fodder is scarce and animals are fed only with dry fodder. It was released in 1981 from Choudhary Charan Singh, Haryana Agricultural University, Hisar for cultivation in whole of India.

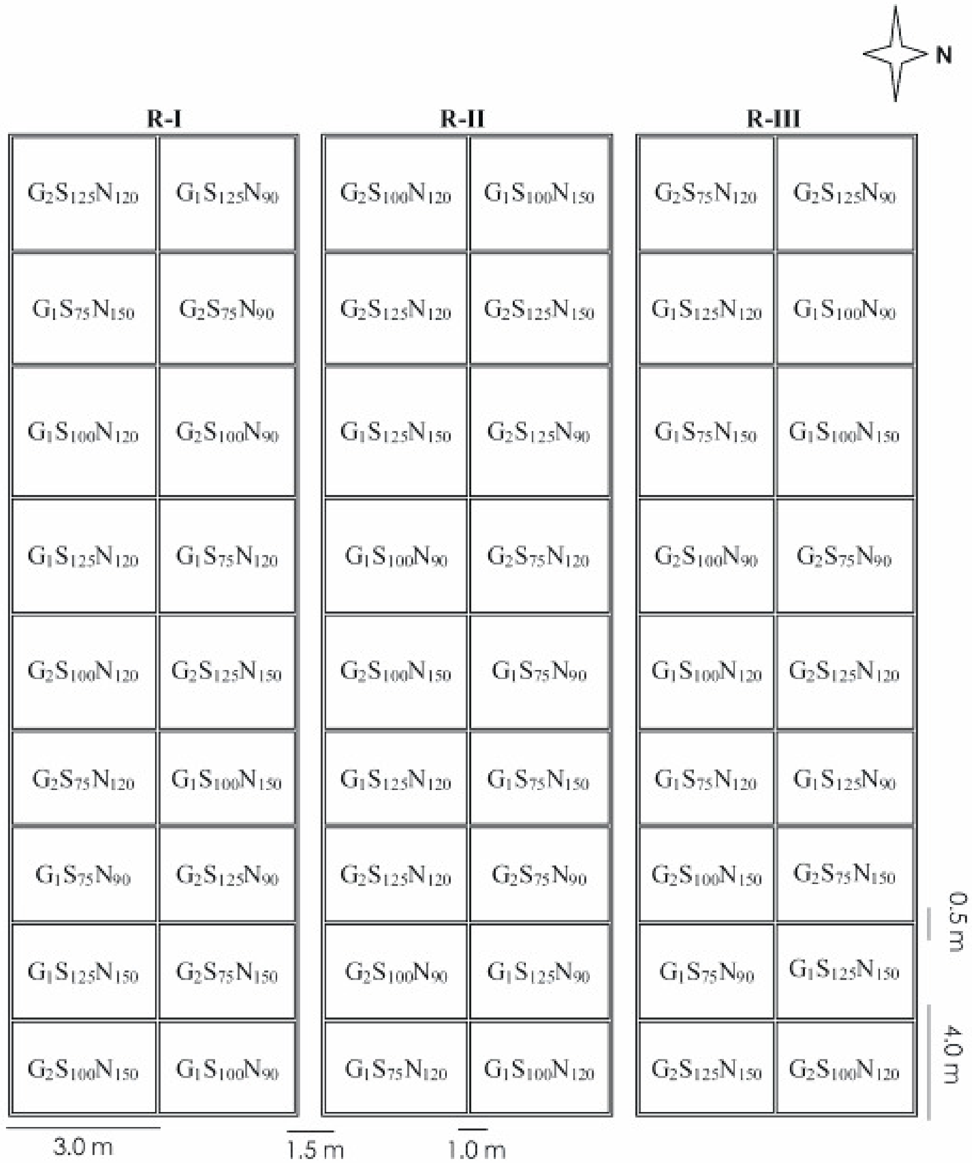
3.6.4 After care

To check the weed growth and to facilitate good growth of the crop, hand weeding was carried out once at 15 days after sowing (DAS) and inter cultivation was carried out at 30 DAS.

LEGEND

Treatment details

Treatment	Notation	Details
T_1	$G_1S_1N_1$	Genotype OS-6 at 75 kg ha^{-1} seed rate with 90 kg ha^{-1} nitrogen
T_2	$G_1S_1N_2$	Genotype OS-6 at 75 kg ha^{-1} seed rate with 120 kg ha^{-1} nitrogen
T_3	$G_1S_1N_3$	Genotype OS-6 at 75 kg ha^{-1} seed rate with 150 kg ha^{-1} nitrogen
T_4	$G_1S_2N_1$	Genotype OS-6 at 100 kg ha^{-1} seed rate with 90 kg ha^{-1} nitrogen
T_5	$G_1S_2N_2$	Genotype OS-6 at 100 kg ha^{-1} seed rate with 120 kg ha^{-1} nitrogen
T_6	$G_1S_2N_3$	Genotype OS-6 at 100 kg ha^{-1} seed rate with 150 kg ha^{-1} nitrogen
T_7	$G_1S_3N_1$	Genotype OS-6 at 125 kg ha^{-1} seed rate with 90 kg ha^{-1} nitrogen
T_8	$G_1S_3N_2$	Genotype OS-6 at 125 kg ha^{-1} seed rate with 120 kg ha^{-1} nitrogen
T_9	$G_1S_3N_3$	Genotype OS-6 at 125 kg ha^{-1} seed rate with 150 kg ha^{-1} nitrogen
T_{10}	$G_2S_1N_1$	Genotype JHO-822 at 75 kg ha^{-1} seed rate with 90 kg ha^{-1} nitrogen
T_{11}	$G_2S_1N_2$	Genotype JHO-822 at 75 kg ha^{-1} seed rate with 120 kg ha^{-1} nitrogen
T_{12}	$G_2S_1N_3$	Genotype JHO-822 at 75 kg ha^{-1} seed rate with 150 kg ha^{-1} nitrogen
T_{13}	$G_2S_2N_1$	Genotype JHO-822 at 100 kg ha^{-1} seed rate with 90 kg ha^{-1} nitrogen
T_{14}	$G_2S_2N_2$	Genotype JHO-822 at 100 kg ha^{-1} seed rate with 120 kg ha^{-1} nitrogen
T_{15}	$G_2S_2N_3$	Genotype JHO-822 at 100 kg ha^{-1} seed rate with 150 kg ha^{-1} nitrogen
T_{16}	$G_2S_3N_1$	Genotype JHO-822 at 125 kg ha^{-1} seed rate with 90 kg ha^{-1} nitrogen
T_{17}	$G_2S_3N_2$	Genotype JHO-822 at 125 kg ha^{-1} seed rate with 120 kg ha^{-1} nitrogen
T_{18}	$G_2S_3N_3$	Genotype JHO-822 at 125 kg ha^{-1} seed rate with 150 kg ha^{-1} nitrogen



Genotype

1) OS-6 (G-1)

2) JHO-822(G-2)

Seed rate (kg ha^{-1})

1) 75 (S_{75})

2) 100 (S_{100})

3) 125 (S_{125})

Nitrogen Levels (kg ha^{-1})

1) 90 (N_{90})

2) 120 (N_{120})

3) 150 (N_{150})

Fig. 2: Plan of layout of the experiment

Fig.2: Plan of layout of the experiment

At 30 days after sowing

At first harvest

At second harvest

Plate 1. General view of the experimental plot

Genotype OS-6

Genotypes JHO-822

Plate 2. Oat genotypes

Table 3: Procedure for recording observations on different parameters

Sl. No.	Parameter	Procedure
I. Growth parameter		
1	Plant height (cm)	The height of five main shoots from sampling units was measured in cm and averaged. The height measurement was taken from ground level to the base of the fully opened youngest leaf before heading and to the tip of panicle after heading.
2	Number of shoots (per m row length)	Total number of shoots (tillers) from demarketed two sampling units as detailed above were counted and expressed as average shoot number per meter linear row.
3	Number of seedlings (per m row length)	Total number of seedlings from demarketed two sampling units as detailed above were counted and expressed as average seedling number per meter linear row.
4	Fresh weight (per m row length)	The plant samples drawn for determination of leaf to stem ratio were utilized to determine the fresh weight. The total fresh weight from 0.5 meter row length was divided by respective tiller number to record fresh weight per shoot in g.
5	Leaf to stem ratio (LSR)	Worked out by using the formula LSR= Dry weight of leaf plant $^{-1}$ / Dry weight of stem plant $^{-1}$
6	Dry matter accumulation (g plant^{-1})	The plant samples taken from sampling units of 0.5 meter linear row length were utilized for determination of dry matter accumulation. Plants were separated into leaves and stem and oven dried at 70^{0}C for 48-72 hours to a constant weight and dry weights were recorded in g. Based on dry weight and number of shoots in sampling units, the dry weight per shoot was worked out at different harvests. But at 30 DAS, samples outside net plot were utilized for determination of dry matter accumulation.

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Sl. No.	Parameter	Procedure
II. Yield parameter		
1	Green forage yield (t ha^{-1})	The shoots from the net plot area were harvested leaving 10 cm from the ground level. After harvesting, the produce was weighed in kg from individual plots and was converted and expressed as green forage yield (GFY) in tonnes (t) per ha.
2	Dry matter yield (t ha^{-1})	The samples drawn for dry matter accumulation studies at each harvest were utilized for calculating dry matter yield (DMY). The fresh weight of the samples were recorded and dried in hot air oven at 70^0C for 48-72 hours to record the dry weight and dry matter percentage was determined. The plot-wise green forage yield was multiplied by respective dry matter percentage to get dry weight in kg per plot and was expressed in t per ha.
III. Proximate analysis for forage quality		
1	Organic matter (%)	Organic matter (OM) content was calculated by the formula OM % = 100- Total ash (%)
2	Organic matter yield (kg/ha)	The organic matter yield was worked out by multiplying the organic matter percentage with dry matter yield
3	Plant nitrogen content (%)	The nitrogen content of whole plant was estimated by modified microkjeldhal method (Banerjee, 1978) and expressed in percentage.
4	Crude protein content (CP) in whole plant (%) (AOAC, 2001)	Crude protein (CP) content in whole plant on oven dry weight basis was worked out by kjeldhal method using the formula CP = % N X 6.25 and expressed in percentage
5	Crude protein yield (kg/ha)	Crude protein yield was worked out by multiplying the crude protein percentage with dry matter yield.
6	Ether extract content (%) (AOAC, 2001)	Ether Extract content in whole plant was estimated by petroleum ether extraction method EE(%) = Weight of ether extract/ Weight of the sample x 100
7.	Ether extract yield (kg/ha)	Ether extract yield was worked out by multiplying the ether extract percentage with dry matter yield.

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Sl. No.	Parameter	Procedure
8	Crude fibre (CF) content (%) (AOAC, 2001)	Crude fibre content in whole plant was estimated by acid-alkali digestion method CF (%) = (weight before ashing)- (weight after ashing) /weight of the sample taken x 100
9	Crude fibre yield (kg/ha)	Crude fibre yield was worked out by multiplying the crude fibre percentage with dry matter yield.
10	Total ash (TA) content (%)	Ash is the inorganic component of the sample left after complete ignition of the sample at 600° C in muffle furnace. It was calculated by using the formula Total ash (%) = weight of ash/ weight of sample X 100
11	Total ash yield (kg/ha)	The total ash yield was worked out by multiplying the percent total ash with dry matter yield
12	Nitrogen free extract (%)	Nitrogen free extract (NFE) content was calculated by using the formula NFE (%) = 100-[Crude protein(%) + Crude fibre(%) + Ether extract(%) +Total Ash (%)]
13	Nitrogen free extract yield (kg/ha)	The nitrogen free extract yield was worked out by multiplying the nitrogen free extract percentage with dry matter yield.
14	Total carbohydrate content (%)	Total carbohydrate(TCHO) content was calculated by using the formula TCHO (%) = NFE (%) + CF (%)
15	Total carbohydrate yield (kg/ha)	The total carbohydrate yield was worked by multiplying the total carbohydrate percentage with dry matter yield.
IV. Palatability		
1	Palatability (%)	Palatability was studied by feeding a known weight of fresh sample from the experimental plot treatment wise to four to five year's old cows in the morning. The leftover sample was weighed and palatability was calculated and expressed in percentage. Palatability (%) = Weight of the fresh fodder offered –Weight of the leftover fodder / Weight of the fresh fodder offered X 100

Contd……

Sl. No.	Parameter	Procedure
V.	**Nitrogen uptake**	
1.	Plant nitrogen uptake	Based on the per cent nutrient content after chemical analysis and dry weight of the plants, the uptake of nutrient were worked out and expressed in kg ha^{-1}. Nutrient uptake (kg ha^{-1}) = % Nutrient concentration x biomass (kg ha^{-1}) /100
2	Available nitrogen in soil	Available soil nitrogen was estimated by alkaline permanganate oxidation method as outlined by Subbiah and Asija (1956).
VI	**Economic analysis**	
1	Benefit cost ratio (B:C)	The cost of cultivation and gross returns per ha for each treatment was computed based on the prices of inputs and outputs that were prevailing at the time of their use during the period of experimentation. The net returns per ha was calculated by deducting the total cost of cultivation from the total monetary value of the produce. To know the rate of return per rupee invested, benefit cost ratio (B:C) was worked out by using the formula B:C = Gross returns (Rs. ha^{-1}) / Total cost of cultivation (Rs. ha^{-1}).

3.6.5 Irrigation schedule

Irrigation at an interval of 12 – 15 days were provided so as to maintain adequate soil moisture based on climatic conditions.

3.6.6 Harvesting

The crop was harvested at 50% flowering stage and fresh weight of fodder was recorded separately treatment wise.

3.7 Collection of experimental data and plant sampling

Five plants were selected at random from each plot at harvest for recording various biometric observations. The parameter and procedures followed to record the observations on each parameter are presented in Table 3.

3.8 Statistical analysis and interpretation of data

The experimental data were statistically analyzed using MSTAT-C programme. The level of significance used in F test was P=0.05. The mean value of the three factors and treatment combinations were subjected to Duncan's Multiple Range Test (DMRT) using the corresponding error mean sum of squares and degrees of freedom values (Gomez and Gomez, 1984). The means followed by the same lower case letter/s do not differ significantly at 0.05 probability level.

4. EXPERIMENTAL RESULTS

The results of field experiment on yield attributes, ancillary characters, forage yield, quality parameters and economics of fodder oat are presented in this chapter.

4.1 Growth parameters

4.1.1 Plant height (cf. Table 4)

At 30 days after sowing (DAS), and at second harvest, genotypes did not differ significantly for plant height. However, during first harvest, there was significant difference among the genotypes. The genotype JHO-822 recorded significantly higher plant height (91.25 cm) over OS-6 (85.38 cm).

With increase in seed rate, there was linear and significant increase in plant height at first and second harvests. However at 30 DAS, the effect was non significant. During first and second harvests, the seed rate of 125 kg ha^{-1} recorded significantly taller plant (91.61 cm and 56.18 cm, respectively) over rest of the seed rates. Significantly lower plant height was recorded with 75 kg ha^{-1} seed rate (84.44 cm and 45.22 cm, respectively).

The nitrogen levels influenced the plant height significantly at all the growth stages. The increase was linear and significant with increase in nitrogen level at first and second harvests. Application of nitrogen at 150 kg ha^{-1} recorded significantly more plant height over other nitrogen levels at 30 DAS, first harvest and second harvest, (5.37 cm, 92.13 cm and 51.87 cm, respectively). Significantly lower plant height was recorded with the application of nitrogen at 90 kg ha^{-1} at 30 DAS (4.79 cm), first harvest (84.79 cm) and second harvest (48.43 cm).

Interaction effect was significant only at first and second harvests. During first harvest, interaction $G_2S_3N_3$ *i.e.* genotype JHO-822 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen recorded significantly higher plant height (100.67 cm) over rest of the treatment combinations. Next best combination for plant height was $G_1S_3N_3$ *i.e.* genotype OS-6 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen (93.40 cm). Significantly lower plant height was recorded in treatment combination of $G_1S_1N_1$ *i.e.* genotype OS-6 with 75 kg ha^{-1} seed rate at 90 kg ha^{-1} nitrogen (79.67 cm).

During second harvest, the interaction $G_2S_3N_3$ *i.e.* genotype JHO-822 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen recorded significantly higher plant height (60.37 cm) over rest of the treatment combinations except with $G_1S_3N_3$ *i.e.* genotype OS-6 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen (59.07 cm). Significantly lower plant height was recorded in $G_1S_1N_1$ *i.e.* genotype OS-6 with 75 kg ha^{-1} seed rate at 90 kg ha^{-1} nitrogen (44.57 cm).

4.1.2 Number of shoots per meter row length (cf. Table 5)

At 30 DAS, oat genotypes did not differ significantly for number of shoots per meter row length. However, during first and second harvests, genotype JHO-822 recorded significantly more number of shoots per meter row length (219.04 and 134.70, respectively) over OS-6 (216.56 and 132.96, respectively).

With increase in seed rate there was linear and significant increase in number of shoots per meter row length at 30 DAS, first and second harvests. The seed rate of 125 kg per ha recorded significantly more number of shoots per meter row length (142.17, 224.50 and 140.11, respectively) over rest of the seed rates. Significantly lower number of shoots per meter row length was recorded with 75 kg per ha seed rate (126.39, 207.83 and 127.44, respectively).

The nitrogen levels significantly influenced the number of shoots per meter row length at all the growth stages and the increase was linear and significant with increase in nitrogen level. Nitrogen level of 150 kg per ha recorded significantly higher number of shoots per meter row length (141.78, 230.44 and 137.61, respectively at 30 DAS, first and second harvests). Significantly lower number of shoots per meter row length was recorded with the application of nitrogen at 90 kg per ha at 30 DAS, first and second harvest (128.28, 204.39 and 131.00, respectively).

Table 4: Plant height (cm) of oat genotypes as influenced by seed rate and nitrogen levels

Treatment	30 DAS	First harvest	Second harvest
Genotype (G)			
G_1 – OS-6	4.97 a	85.38 b	49.98 a
G_2 - JHO-822	5.16 a	91.25 a	50.03 a
S.Em. ±	0.10	0.33	0.32
Seed rate (S) kg ha^{-1}			
S_1 – S_{75}	4.92 a	84.44 c	45.22 b
S_2 – S_{100}	5.14 a	88.89 b	48.61 b
S_3 – S_{125}	5.15 a	91.61 a	56.18 a
S.Em. ±	0.12	0.41	0.40
Nitrogen level (N) kg ha^{-1}			
N_1 - 90	4.79 b	84.79 c	48.43 c
N_2 - 120	5.05 b	88.02 b	49.71 b
N_3 - 150	5.37 a	92.13 a	51.87 a
S.Em. ±	0.12	0.41	0.40
Interaction (G × S × N)			
G_1 S_1 N_1	4.59 a	79.67 g	44.57 f
G_1 S_1 N_2	4.62 a	82.80 ef	45.20 f
G_1 S_1N_3	5.11 a	83.60 d-f	46.30 ef
G_1 S_2 N_1	4.96 a	84.27 d-f	46.87 d-f
G_1 S_2 N_2	5.04 a	86.73 cd	48.83 c-e
G_1 S_2 N_3	5.16 a	88.33 c	49.93 c-d
G_1 S_3 N_1	4.91 a	83.67 d-f	53.93 b
G_1 S_3 N_2	5.16 a	85.93 c-e	55.13 b
G_1 S_3 N_3	5.22 a	93.40 b	59.07 a
G_2 S_1 N_1	4.74 a	82.13 fg	44.70 f
G_2 S_1 N_2	4.79 a	86.00 c-e	45.10 f
G_2 S_1 N_3	5.65 a	92.47 b	45.43 f
G_2 S_2 N_1	4.65 a	86.40 cd	47.03 d-f
G_2 S_2 N_2	5.38 a	93.27 b	48.87 c-e
G_2 S_2 N_3	5.62 a	94.33 b	50.13 c
G_2 S_3 N_1	4.89 a	92.60 b	53.50 b
G_2 S_3 N_2	5.29 a	93.40 b	55.10 b
G_2 S_3 N_3	5.45 a	100.67 a	60.37 a
S.Em. ±	0.30	1.00	0.97

DAS: Days after sowing
Means followed by the same lower case letter/s in a column do not differ significantly by DMRT ($P = 0.05$)

Table 5: Number of shoots per m row length of oat genotypes as influenced by seed rate and nitrogen levels

Treatment	30 DAS	First harvest	Second harvest
Genotype (G)			
G_1 – OS-6	134.33 a	216.56 b	132.96 b
G_2 - JHO-822	134.22 a	219.04 a	134.70 a
S.Em. ±	0.30	0.43	0.44
Seed rate (S) kg ha^{-1}			
S_1 – S_{75}	126.39 c	207.83 c	127.44 c
S_2 – S_{100}	134.28 b	221.06 b	133.94 b
S_3 – S_{125}	142.17 a	224.50 a	140.11 a
S.Em. ±	0.37	0.53	0.54
Nitrogen level (N) kg ha^{-1}			
N_1 - 90	128.28 c	204.39 c	131.00 c
N_2 - 120	132.78 b	218.56 b	132.89 b
N_3 - 150	141.78 a	230.44 a	137.61 a
S.Em. ±	0.37	0.53	0.54
Interaction (G × S × N)			
G_1 S_1 N_1	118.67 f	178.00 g	124.67 ij
G_1 S_1 N_2	123.67 e	214.33 e	127.00 h-j
G_1 S_1N_3	136.00 c	225.00 b	129.33 f-h
G_1 S_2 N_1	129.33 d	214.33 e	131.33 f-g
G_1 S_2 N_2	130.67 d	218.33 c-e	132.67 ef
G_1 S_2 N_3	143.00 b	228.67 b	136.00 c-e
G_1 S_3 N_1	138.33 c	214.67 de	136.33 c-e
G_1 S_3 N_2	143.33 b	220.67 c	137.00 cd
G_1 S_3 N_3	146.00 a	235.00 a	142.33 b
G_2 S_1 N_1	118.67 f	184.00 f	123.33 j
G_2 S_1 N_2	125.33 e	218.67 cd	128.00 g-i
G_2 S_1 N_3	136.00 c	227.00 b	132.33 ef
G_2 S_2 N_1	129.00 d	217.33 c-e	132.67 ef
G_2 S_2 N_2	130.67 d	218.67 cd	133.33 d-f
G_2 S_2 N_3	143.00 b	229.00 b	137.67 c
G_2 S_3 N_1	135.67 c	218.00 c-e	137.67 c
G_2 S_3 N_2	143.00 b	220.67 c	139.33 bc
G_2 S_3 N_3	146.67 a	238.00 a	148.00 a
S.Em. ±	0.90	1.30	1.32

DAS: Days after sowing
Means followed by the same lower case letter/s in a column do not differ significantly by DMRT ($P = 0.05$)

Interaction effect was significant at 30 DAS, first and second harvests. Interaction $G_2S_3N_3$ *i.e.*, genotype JHO-822 with 125 kg per ha seed rate at 150 kg per ha nitrogen recorded significantly higher number of shoots per meter row length (146.67, 238.00 and 148.00, respectively) over rest of the combinations except $G_1S_3N_3$ *i.e.*, genotype OS-6 with 125 kg per ha seed rate at 150 kg per ha nitrogen during 30 DAS and at first harvest. Next best combination was $G_1S_3N_3$ *i.e.*, genotype OS-6 with 125 kg per ha seed rate at 150 kg per ha nitrogen (146.00, 235.00 and 142.33, respectively). Significantly lower number of shoots per meter row length was recorded in treatment combination of $G_1S_1N_1$ *i.e.*, genotype OS-6 with 75 kg per ha seed rate at 90 kg per ha nitrogen (118.67, 178.00 and 124.67 at 30 DAS, first and second harvests, respectively).

4.1.3 Number of seedlings per meter row length (cf. Table 6)

Oat genotypes did not differ significantly for number of seedlings per meter row length at all the growth stages.

With increase in seed rate, there was linear and significant increase in number of seedlings per meter row length at 30 DAS, first and second harvest. The seed rate of 125 kg per ha recorded significantly more number of seedlings per meter row length (42.06, 44.33 and 39.33, respectively) over rest of the seed rates. Significantly lower number of seedlings per meter row length was recorded with 75 kg per ha seed rate (32.44, 34.33 and 29.33, respectively).

The nitrogen levels influenced the number of seedlings per meter row length significantly at all the growth stages. The increase was significantly more with higher nitrogen level of 150 kg per ha (37.22, 39.22 and 34.22, respectively). It was on par with nitrogen at 120 kg per ha (36.61, 38.83 and 33.83, respectively).

Interaction effect was significant at all the growth stages. Irrespective of genotype and nitrogen levels, the number of seedlings per m row length were significantly higher at higher level of seed rate *i.e.,* 125 kg ha^{-1} and they were on par at 30 DAS and during both the harvests. At first and second harvests, interaction $G_2S_3N_2$ *i.e.*, genotype JHO-822 with 125 kg per ha seed rate at 120 kg per ha nitrogen recorded significantly higher number of seedlings per meter row length (45.67 and 40.67, respectively) followed by $G_2S_3N_3$ *i.e.*, genotype JHO-822 with 125 kg per ha seed rate at 150 kg per ha nitrogen (45.33 and 40.33, respectively) and interaction $G_2S_3N_3$.

4.1.4 Fresh weight per meter row length (cf. Table 7)

Oat genotypes did not differ significantly for fresh weight per meter row length at 30 DAS and at both the harvests.

With increase in seed rate there was linear and significant increase in fresh weight per meter row length at 30 DAS, first and second harvests. The seed rate of 125 kg per ha recorded significantly higher fresh weight per meter row length (92.50, 1237.33 and 398.56 g, respectively) over rest of the seed rates. Significantly lower fresh weight per meter row length was recorded with 75 kg per ha seed rate (86.16, 1037.11 and 3441.11 g, respectively).

The nitrogen levels influenced the fresh weight per m row length significantly at all the growth stages. The increase was linear and significant with increase in nitrogen level. Nitrogen level of 150 kg per ha recorded significantly higher fresh weight per meter row length (94.14, 1150.89 and 378.89 g, respectively at 30 DAS, first and second harvests). Significantly lower fresh weight per meter row length was recorded with the application of nitrogen at 90 kg per ha (85.04, 1127.22 and 363.33 g, respectively at 30 DAS, first and second harvests). Interaction effect was significant at 30 DAS, first and second harvests. It was linear with increase in nitrogen level irrespective of genotype and seed rate. Interaction $G_2S_3N_3$ *i.e.*, genotype JHO-822 with 125 kg per ha seed rate at 150 kg per ha nitrogen recorded significantly higher fresh weight per meter row length (99.40, 1250.00 and 411.00 g, respectively) over rest of the interactions except $G_1S_3N_3$ during 30 DAS and second harvest. Next best combination was $G_1S_3N_3$ *i.e.*, genotype OS-6 with 125 kg per ha seed rate at 150 kg per ha nitrogen (96.43, 1245.33 and 409.67 g, respectively). Significantly lower fresh weight per meter row length was recorded in treatment combination of $G_1S_1N_1$ *i.e.*, genotype OS-6 with 75 kg per ha seed rate at 90 kg per ha nitrogen (81.67, 1028.00 and 339.67 g, at 30 DAS, first and second harvests, respectively).

Table 6: Number of seedlings per m row length of oat genotypes as influenced by seed rate and nitrogen levels

Treatment	30 DAS	First harvest	Second harvest
Genotype (G)			
G_1 – OS-6	36.48 a	38.33 a	33.33 a
G_2 - JHO-822	36.67 a	38.89 a	33.89 a
S.Em. ±	0.31	0.29	0.29
Seed rate (S) kg ha^{-1}			
S_1 – S_{75}	32.44 c	34.33 c	29.33 c
S_2 – S_{100}	35.22 b	37.17 b	32.17 b
S_3 – S_{125}	42.06 a	44.33 a	39.33 a
S.Em. ±	0.38	0.35	0.35
Nitrogen level (N) kg ha^{-1}			
N_1 - 90	35.89 b	37.78 b	32.78 b
N_2 - 120	36.61 ab	38.83 ab	33.83 ab
N_3 - 150	37.22 a	39.22 a	34.22 a
S.Em. ±	0.38	0.35	0.35
Interaction (G × S × N)			
G_1 S_1 N_1	32.00 d	33.33 e	28.33 e
G_1 S_1 N_2	32.67 cd	34.67 c-e	29.67 c-e
G_1 S_1N_3	32.67 cd	34.67 c-e	29.67 c-e
G_1 S_2 N_1	34.00 b-d	36.00 b-e	31.00 b-e
G_1 S_2 N_2	35.00 b-d	37.00 b-d	32.00 b-d
G_1 S_2 N_3	36.00 b	37.67 b	32.67 b
G_1 S_3 N_1	41.00 a	43.00 a	38.00 a
G_1 S_3 N_2	42.00 a	43.67 a	38.67 a
G_1 S_3 N_3	43.00 a	45.00 a	40.00 a
G_2 S_1 N_1	32.00 d	34.33 de	29.33 de
G_2 S_1 N_2	32.67 cd	34.67 c-e	29.67 c-e
G_2 S_1 N_3	32.67 cd	34.33 de	29.33 de
G_2 S_2 N_1	35.00 b-d	36.67 b-d	31.67 b-d
G_2 S_2 N_2	35.33 bc	37.33 bc	32.33 bc
G_2 S_2 N_3	36.00 b	38.33 b	33.33 b
G_2 S_3 N_1	41.33 a	43.33 a	38.33 a
G_2 S_3 N_2	42.00 a	45.67 a	40.67 a
G_2 S_3 N_3	43.00 a	45.33 a	40.33 a
S.Em. ±	0.94	0.87	0.87

DAS: Days after sowing
Means followed by the same lower case letter/s in a column do not differ significantly by DMRT ($P = 0.05$)

Table 7: Fresh weight (g per m row length) of oat genotypes as influenced by seed rate and nitrogen levels

Treatment	30 DAS	First harvest	Second harvest
Genotype (G)			
G_1 – OS-6	89.25 a	1138.81 a	369.07 a
G_2 - JHO-822	89.71 a	1140.07 a	369.78 a
S.Em. ±	0.47	0.46	0.76
Seed rate (S) kg ha^{-1}			
S_1 – S_{75}	86.16 c	1037.11 c	344.11 c
S_2 – S_{100}	89.78 b	1143.89 b	365.61 b
S_3 – S_{125}	92.50 a	1237.33 a	398.56 a
S.Em. ±	0.58	0.56	0.93
Nitrogen level (N) kg ha^{-1}			
N_1 - 90	85.04 c	1127.22 c	363.33 c
N_2 - 120	89.27 b	1140.22 b	366.06 b
N_3 - 150	94.14 a	1150.89 a	378.89 a
S.Em. ±	0.58	0.56	0.93
Interaction (G × S × N)			
G_1 S_1 N_1	81.67 f	1028.00 k	339.67 f
G_1 S_1 N_2	85.89 ef	1037.67 j	340.67 f
G_1 S_1N_3	91.21 cd	1047.33 i	351.33 e
G_1 S_2 N_1	86.41 e	1128.00 h	359.67 d
G_1 S_2 N_2	89.60 c-e	1144.67 g	361.33 d
G_1 S_2 N_3	93.02 bc	1156.67 f	375.00 c
G_1 S_3 N_1	86.10 e-f	1225.33 e	390.33 b
G_1 S_3 N_2	92.93 bc	1236.33 c	394.00 b
G_1 S_3 N_3	96.43 ab	1245.33 b	409.67 a
G_2 S_1 N_1	81.72 f	1024.67 k	339.67 f
G_2 S_1 N_2	85.22 ef	1037.67 j	342.33 f
G_2 S_1 N_3	91.25 cd	1047.33 i	351.00 e
G_2 S_2 N_1	86.74 de	1128.00 h	360.00 d
G_2 S_2 N_2	89.42 c-e	1147.33 g	362.33 d
G_2 S_2 N_3	93.51 bc	1158.67 f	375.33 c
G_2 S_3 N_1	87.60 de	1229.33 d	390.67 b
G_2 S_3 N_2	92.55 bc	1237.67 c	395.67 b
G_2 S_3 N_3	99.40 a	1250.00 a	411.00 a
S.Em. ±	1.41	1.38	2.29

DAS: Days after sowing
Means followed by the same lower case letter/s in a column do not differ significantly by DMRT ($P = 0.05$)

4.1.5 Leaf to stem ratio (cf. Table 8)

The oat genotypes did not influence the leaf to stem ratio significantly during 30 DAS, first and second harvests.

During 30 DAS and first harvest, the effect of seed rate was non-significant. During second harvest, higher seed rate of 125 kg per ha recorded significantly higher leaf to stem ratio (0.514). Significantly lower leaf to stem ratio was recorded with 75 kg per ha seed rate (0.497) and it was on par with 100 kg per ha seed rate.

During 30 DAS, the effect of nitrogen levels on leaf to stem ratio was non-significant. During first and second harvest, application of nitrogen at 150 kg per ha recorded significantly more leaf to stem ratio (2.43 and 0.514, respectively) over rest of the nitrogen levels. Significantly lower leaf to stem ratio was recorded with the application of nitrogen at 90 kg per ha (1.79 and 0.496, respectively).

At 30 DAS, interaction effect was not significant. However,it ranged from 2.26 to 2.64 . During first and second harvests, interaction $G_2S_3N_3$ *i.e.*, genotype JHO-822 with 125 kg per ha seed rate at 150 kg per ha nitrogen recorded significantly higher leaf to stem ratio (2.47 and 0.533, respectively). It was on par with $G_1S_3N_3$ *i.e.*, genotype OS-6 with 125 kg per ha seed rate at 150 kg per ha nitrogen (2.40 and 0.527, respectively). Significantly lower leaf to stem ratio was recorded in treatment combination $G_2S_3N_1$ *i.e.*, genotype JHO-822 with 125 kg per ha seed rate at 90 kg per ha nitrogen (1.73) during first harvest and $G_1S_2N_2$ *i.e.*, genotype OS-6 with 125 kg per ha seed rate at 120 kg per ha nitrogen (0.476) during second harvest.

4.1.6 Dry matter accumulation in leaf (cf. Table 9)

The genotypes did not differ significantly for dry matter accumulation in leaf at all the stages of crop growth.

The seed rate influenced the dry matter accumulation in leaf significantly at both the harvests. However, the difference was negligible (0.003 g plant^{-1}).

Effect of nitrogen levels was also significant at both the harvests, but the difference was negligible. There was significantly higher dry matter accumulation in leaf at first harvest (0.346 g plant^{-1}) and second harvest (0.266 g plant^{-1}) with nitrogen level of 150 kg ha^{-1}.

Interaction effect was significant for dry matter accumulation in leaf during both the harvests. It ranged from 0.083 to 0.084 g plant^{-1} at 30 DAS, 0.337 to 0.348 g plant^{-1} at first harvest and 0.260 to 0.271 g plant^{-1} at second harvest. However, treatment combination $G_2S_3N_3$ recorded significantly higher dry matter accumulation in leaf.

4.1.7 Dry matter accumulation in stem (cf. Table 10)

The genotypes did not differ significantly for dry matter accumulation in stem at all the stages of crop growth.

The seed rate influenced the dry matter accumulation in stem at both the harvests. However, the difference was negligible (0.003 g plant^{-1}).

Effect of nitrogen levels was also significant at both the harvests, but the difference was negligible. There was significantly higher dry matter accumulation in stem at first harvest (0.182 g plant^{-1}) and second harvest (0.531 g plant^{-1}) at 90 kg ha^{-1} nitrogen.

Interaction effect was significant for dry matter accumulation in stem but the difference was negligible. It ranged from 0.040 to 0.042 g plant^{-1} at 30DAS, 0.183 to 0.176 g plant^{-1} at first harvest and 0.532 to 0.527 g plant^{-1} at second harvest. However, combination of $G_1S_1N_1$ recorded significantly higher dry matter accumulation in stem during both the harvests.

4.1.8 Total dry matter accumulation (cf. Table 11)

The genotypes and seed rates did not differ significantly for total dry matter accumulation per plant at all the stages of crop growth.

Effect of nitrogen levels was significant only at first harvest, but the difference was negligible. There was significantly higher total dry matter accumulation at first harvest (0.524 g plant^{-1}) with 125 kg ha^{-1} nitrogen.

Table 8: Leaf to stem ratio of oat genotypes as influenced by seed rate and nitrogen levels

Treatment	30 DAS	First harvest	Second harvest
Genotype (G)			
G_1 – OS-6	2.45 a	2.10 a	0.501 a
G_2 - JHO-822	2.50 a	2.10 a	0.505 a
S.Em. ±	0.06	0.03	0.003
Seed rate (S) kg ha^{-1}			
S_1 – S_{75}	2.37 a	2.11 a	0.497 b
S_2 – S_{100}	2.52 a	2.06 a	0.498 b
S_3 – S_{125}	2.53 a	2.12 a	0.514 a
S.Em. ±	0.07	0.04	0.003
Nitrogen level (N) kg ha^{-1}			
N_1 - 90	2.46 a	1.79 c	0.496 b
N_2 - 120	2.46 a	2.08 b	0.498 b
N_3 - 150	2.51 a	2.43 a	0.514 a
S.Em. ±	0.07	0.04	0.003
Interaction (G × S × N)			
G_1 S_1 N_1	2.32 a	1.76 c	0.489 cd
G_1 S_1 N_2	2.45 a	2.03 c-g	0.496 cd
G_1 S_1N_3	2.31 a	2.53 a	0.504 bc
G_1 S_2 N_1	2.43 a	1.77 g	0.497 cd
G_1 S_2 N_2	2.53 a	2.03 c-g	0.476 d
G_1 S_2 N_3	2.64 a	2.47 a	0.506 bc
G_1 S_3 N_1	2.50 a	1.80 fg	0.502 b-d
G_1 S_3 N_2	2.49 a	2.10 b-e	0.508 a-c
G_1 S_3 N_3	2.36 a	2.40 a	0.527 ab
G_2 S_1 N_1	2.28 a	1.87 e-g	0.490 cd
G_2 S_1 N_2	2.26 a	2.09 b-f	0.497 cd
G_2 S_1 N_3	2.61 a	2.38 ab	0.503 bc
G_2 S_2 N_1	2.60 a	1.80 fg	0.495 cd
G_2 S_2 N_2	2.41 a	2.00 d-g	0.502 b-d
G_2 S_2 N_3	2.52 a	2.30 a-c	0.510 a-c
G_2 S_3 N_1	2.60 a	1.73 g	0.504 bc
G_2 S_3 N_2	2.63 a	2.24 a-d	0.511 a-c
G_2 S_3 N_3	2.62 a	2.47 a	0.533 a
S.Em. ±	0.18	0.09	0.008

DAS: Days after sowing
Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

Table 9: Dry matter accumulation in leaves of oat genotypes as influenced by seed rate and nitrogen levels

Treatment	Dry matter accumulation in leaves (g $plant^{-1}$)		
	30 DAS	First harvest	Second harvest
Genotype (G)			
G_1 – OS-6	0.083 a	0.341 a	0.263 a
G_2 - JHO-822	0.084 a	0.342 a	0.264 a
S.Em. ±	0.001	0.001	0.001
Seed rate (S) kg ha^{-1}			
S_1 – S_{75}	0.084 a	0.340 b	0.262 b
S_2 – S_{100}	0.084 a	0.341 ab	0.263 ab
S_3 – S_{125}	0.084 a	0.343 a	0.265 a
S.Em. ±	0.001	0.001	0.001
Nitrogen level (N) kg ha^{-1}			
N_1 - 90	0.083 a	0.338 c	0.261 b
N_2 - 120	0.084 a	0.341 b	0.263 b
N_3 - 150	0.084 a	0.346 a	0.266 a
S.Em. ±	0.001	0.001	0.001
Interaction (G × S × N)			
$G_1 S_1 N_1$	0.083 a	0.337 d	0.260 c
$G_1 S_1 N_2$	0.083 a	0.339 b-d	0.262 bc
$G_1 S_1 N_3$	0.084 a	0.344 a-c	0.263 bc
$G_1 S_2 N_1$	0.083 a	0.337 d	0.260 b
$G_1 S_2 N_2$	0.083 a	0.339 b-d	0.262 bc
$G_1 S_2 N_3$	0.084 a	0.345 ab	0.264 bc
$G_1 S_3 N_1$	0.083 a	0.338 cd	0.261 bc
$G_1 S_3 N_2$	0.083 a	0.340 b-d	0.263 bc
$G_1 S_3 N_3$	0.084 a	0.346 a	0.267 ab
$G_2 S_1 N_1$	0.083 a	0.337 d	0.261 bc
$G_2 S_1 N_2$	0.084 a	0.339 b-d	0.263 bc
$G_2 S_1 N_3$	0.084 a	0.344 a-c	0.264 bc
$G_2 S_2 N_1$	0.083 a	0.337 d	0.261 bc
$G_2 S_2 N_2$	0.084 a	0.340 b-d	0.263 bc
$G_2 S_2 N_3$	0.084 a	0.345 ab	0.265 bc
$G_2 S_3 N_1$	0.083 a	0.339 b-d	0.262 bc
$G_2 S_3 N_2$	0.084 a	0.345 ab	0.264 bc
$G_2 S_3 N_3$	0.084 a	0.348 a	0.271 a
S.Em. ±	0.002	0.002	0.002

DAS: Days after sowing

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT ($P = 0.05$)

Interaction effect was non-significant for total dry matter accumulation at all the crop growth stages. It ranged from 0.125 to 0.124 g plant^{-1} at 30 DAS, 0.524 to 0.519 g plant^{-1} at first harvest and 0.798 to 0.792 g plant^{-1} at second harvest.

4.2 Yield and yield components

4.2.1 Green forage yield (cf. Table 12)

There was significant difference in total green forage yield of oat due to genotypes, levels of seed rate and nitrogen and their interaction.

The oat genotypes differed significantly with respect to total green forage yield of two harvests. The genotype JHO-822 recorded significantly higher total green forage yield (57.21 t ha^{-1}) compared to the genotype OS-6 (55.30 t ha^{-1}). Similar trend was noticed during first harvest with JHO-822 recording 34.37 t ha^{-1} and OS-6 with 32.87 t ha^{-1} green forage yield. However, there was no significant difference among the genotypes during the second harvest.

There was linear and significant increase in green forage yield of oat genotypes with increase in seed rate from 75 to 125 kg ha^{-1}. Seed rate of 125 kg ha^{-1} recorded significantly higher total green forage yield (62.29 t ha^{-1}) over rest of the seed rates and similar trend was noticed during first and second harvests (37.20 and 25.09 t ha^{-1}, respectively). However, significantly least total green forage yield was recorded with seed rate of 75 kg ha^{-1} (51.46 t ha^{-1}).

Total green forage yield of oat also increased linearly and significantly with increase in nitrogen level from 90 to 150 kg ha^{-1}. Application of nitrogen at 150 kg ha^{-1} recorded significantly higher total green forage yield (62.58 t ha^{-1}) compared to lower doses and similar trend was noticed during first (38.44 t ha^{-1}) and second (24.14 t ha^{-1}) harvests. Significantly least total green forage yield (51.27 t ha^{-1}) was recorded with 90 kg ha^{-1} nitrogen.

The treatment combination $G_2S_3N_3$ *i.e.* genotype JHO-822 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen recorded significantly higher total green forage yield (73.83 t ha^{-1}) compared to rest of the combinations and it was followed by $G_1S_3N_3$ *i.e.* genotype OS-6 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen (70.49 t ha^{-1}). Similar trend was noticed during first and second harvests (46.07 and 27.77 t ha^{-1}, respectively). However, significantly lower total green forage yield was recorded with $G_1S_1N_1$ *i.e.* genotype OS-6 with 75 kg ha^{-1} seed rate at 90 kg ha^{-1} nitrogen (47.77 t ha^{-1}). Similar trend was noticed during first and second harvests also.

4.2.2 Dry matter yield (cf. Table 13)

Total dry matter yield of oat differed significantly due to genotypes, levels of seed rate and nitrogen and their interaction.

The oat genotypes differed significantly with respect to total dry matter yield of two harvests. The genotype JHO-822 recorded significantly higher total dry matter yield (10.87 t ha^{-1}) compared to the genotype OS-6 (10.51 t ha^{-1}). Similar trend was noticed during first harvest with JHO-822 recording 6.53 t ha^{-1} and OS-6 with 6.24 t ha^{-1} dry matter yield. However, there was no significant difference among the genotypes during the second harvest.

There was linear and significant increase in dry matter yield of oat genotypes with increase in seed rate from 75 to 125 kg ha^{-1}. Seed rate of 125 kg ha^{-1} recorded significantly higher total dry matter yield (11.83t ha^{-1}) over rest of the seed rates and similar trend was noticed during first and second harvests (7.07 and 4.77 t ha^{-1}, respectively). However, significantly least total dry matter yield was recorded with seed rate of 75 kg ha^{-1} (9.78 t ha^{-1})

Total dry matter yield of oat also increased linearly and significantly with increase in nitrogen level from 90 to 150 kg ha^{-1}. Application of nitrogen at 150 kg ha^{-1} recorded significantly higher total dry matter yield (11.89 t ha^{-1}) compared to lower doses and similar trend was noticed during first (7.30 t ha^{-1}) and second (4.59 t ha^{-1}) harvests. Significantly least total dry matter yield (9.74 t ha^{-1}) was recorded with 90 kg ha^{-1} nitrogen.

Table 10: Dry matter accumulation in stem of oat genotypes as influenced by seed rate and nitrogen levels

Treatment	Dry matter accumulation in stem (g plant^{-1})		
	30 DAS	First harvest	Second harvest
Genotype (G)			
G_1 – OS-6	0.041 a	0.181 a	0.530 a
G_2 - JHO-822	0.041 a	0.179 a	0.529 a
S.Em. ±	0.001	0.001	0.000
Seed rate (S) kg ha^{-1}			
S_1 – S_{75}	0.041 a	0.182 a	0.530 a
S_2 – S_{100}	0.041 a	0.180 a	0.530 a
S_3 – S_{125}	0.041 a	0.179 b	0.529 a
S.Em. ±	0.001	0.001	0.001
Nitrogen level (N) kg ha^{-1}			
N_1 - 90	0.042 a	0.182 a	0.531 a
N_2 - 120	0.041 a	0.180 a	0.530 a
N_3 - 150	0.041 a	0.179 b	0.528 b
S.Em. ±	0.001	0.001	0.001
Interaction (G × S × N)			
G_1 S_1 N_1	0.042 a	0.183 a	0.532 a
G_1 S_1 N_2	0.041 a	0.183 a	0.531 ab
G_1 S_1N_3	0.041 a	0.181 ab	0.530 ab
G_1 S_2 N_1	0.042 a	0.182 ab	0.530 ab
G_1 S_2 N_2	0.041 a	0.181 ab	0.531 ab
G_1 S_2 N_3	0.041 a	0.180 ab	0.529 ab
G_1 S_3 N_1	0.042 a	0.181 ab	0.532 a
G_1 S_3 N_2	0.041 a	0.180 ab	0.529 ab
G_1 S_3 N_3	0.040 a	0.179 ab	0.528 ab
G_2 S_1 N_1	0.042 a	0.183 a	0.531 ab
G_2 S_1 N_2	0.041 a	0.181 ab	0.530 ab
G_2 S_1 N_3	0.040 a	0.180 ab	0.529 ab
G_2 S_2 N_1	0.041 a	0.182 ab	0.531 ab
G_2 S_2 N_2	0.041 a	0.179 ab	0.530 ab
$G_2 S_2$ N_3	0.040 a	0.177 ab	0.529 ab
G_2 S_3 N_1	0.042 a	0.180 ab	0.530 ab
G_2 S_3 N_2	0.040 a	0.179 ab	0.529 ab
G_2 S_3 N_3	0.041 a	0.176 b	0.527 b
S.Em. ±	0.002	0.002	0.001

DAS: Days after sowing
Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

Table 11: Total dry matter accumulation of oat genotypes as influenced by seed rate and nitrogen levels

Treatment	Total dry matter accumulation (g plant^{-1})		
	30 DAS	First harvest	Second harvest
Genotype (G)			
G_1 – OS-6	0.125 a	0.522 a	0.793 a
G_2 - JHO-822	0.125 a	0.521 a	0.793 a
S.Em. ±	0.001	0.001	0.001
Seed rate (S) kg ha^{-1}			
S_1 – S_{75}	0.125 a	0.522 a	0.793 a
S_2 – S_{100}	0.125 a	0.521 a	0.792 a
S_3 – S_{125}	0.125 a	0.522 a	0.793 a
S.Em. ±	0.001	0.001	0.001
Nitrogen level (N) kg ha^{-1}			
N_1 - 90	0.125 a	0.519 b	0.792 a
N_2 - 120	0.124 a	0.521 a	0.793 a
N_3 - 150	0.125 a	0.524 a	0.794 a
S.Em. ±	0.001	0.001	0.001
Interaction (G × S × N)			
G_1 S_1 N_1	0.125 a	0.520 a	0.792 a
G_1 S_1 N_2	0.124 a	0.522 a	0.793 a
G_1 S_1N_3	0.125 a	0.525 a	0.793 a
G_1 S_2 N_1	0.125 a	0.519 a	0.791 a
G_1 S_2 N_2	0.124 a	0.520 a	0.793 a
G_1 S_2 N_3	0.125 a	0.525 a	0.793 a
G_1 S_3 N_1	0.125 a	0.519 a	0.793 a
G_1 S_3 N_2	0.124 a	0.520 a	0.792 a
G_1 S_3 N_3	0.124 a	0.525 a	0.793 a
G_2 S_1 N_1	0.125 a	0.520 a	0.792 a
G_2 S_1 N_2	0.125 a	0.520 a	0.793 a
G_2 S_1 N_3	0.124 a	0.524 a	0.793 a
G_2 S_2 N_1	0.124 a	0.519 a	0.792 a
G_2 S_2 N_2	0.125 a	0.519 a	0.793 a
G_2 S_2 N_3	0.124 a	0.522 a	0.794 a
G_2 S_3 N_1	0.125 a	0.519 a	0.792 a
G_2 S_3 N_2	0.124 a	0.523 a	0.792 a
G_2 S_3 N_3	0.125 a	0.524 a	0.798 a
S.Em. ±	0.002	0.003	0.003

DAS: Days after sowing
Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

Table 12: Green fodder yield of oat genotypes as influenced by seed rate and nitrogen levels

Treatment	Green fodder yield (t ha^{-1})		
	First harvest	Second harvest	Total
Genotype (G)			
G_1 – OS-6	32.87 b	22.43 a	55.30 b
G_2 - JHO-822	34.37 a	22.84 a	57.21 a
S.Em. ±	0.26	0.23	0.35
Seed rate (S) kg ha^{-1}			
S_1 – S_{75}	30.87 c	20.59 c	51.46 c
S_2 – S_{100}	32.78 b	22.22 b	55.00 b
S_3 – S_{125}	37.20 a	25.09 a	62.29 a
S.Em. ±	0.32	0.28	0.43
Nitrogen level (N) kg ha^{-1}			
N_1 - 90	29.86 c	21.41 c	51.27 c
N_2 - 120	32.56 b	22.35 b	54.91 b
N_3 - 150	38.44 a	24.14 a	62.58 a
S.Em. ±	0.32	0.28	0.43
Interaction (G × S × N)			
G_1 S_1 N_1	27.90 k	19.87 g	47.77 k
G_1 S_1 N_2	30.47 h-j	19.95 g	50.42 i-k
G_1 S_1N_3	34.60 de	21.13 e-g	55.73 d-f
G_1 S_2 N_1	28.53 jk	21.10 e-g	49.63 jk
G_1 S_2 N_2	31.80 f-i	21.77 d-g	53.57 f-i
G_1 S_2 N_3	35.10 de	22.60 c-e	57.70 de
G_1 S_3 N_1	30.70 g-j	23.73 b-d	54.43 e-h
G_1 S_3 N_2	33.57 ef	24.35 bc	57.92 d
G_1 S_3 N_3	43.13 b	27.35 a	70.49 b
G_2 S_1 N_1	28.63 jk	20.06 fg	48.70 jk
G_2 S_1 N_2	30.57 h-j	20.99 e-g	51.55 g-j
G_2 S_1 N_3	33.07 eg	21.53 d-g	54.60 d-h
G_2 S_2 N_1	30.00 i-k	21.27 e-g	51.27 h-j
G_2 S_2 N_2	32.60 e-h	22.15 c-g	54.75 d-g
G_2 S_2 N_3	38.67 c	24.43 b-c	63.10 c
G_2 S_3 N_1	33.40 ef	22.41 c-f	55.81 d-f
G_2 S_3 N_2	36.33 d	24.91 b	61.24 c
G_2 S_3 N_3	46.07 a	27.77 a	73.83 a
S.Em. ±	0.78	0.69	1.06

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT ($P = 0.05$)

Table 13: Dry matter yield of oat genotypes as influenced by seed rate and nitrogen levels

Treatment	Dry matter yield (t ha^{-1})		
	First harvest	Second harvest	Total
Genotype (G)			
G_1 – OS-6	6.24 b	4.26 a	10.51 b
G_2 - JHO-822	6.53 a	4.34 a	10.87 a
S.Em. ±	0.05	0.04	0.07
Seed rate (S) kg ha^{-1}			
$S_1 – S_{75}$	5.87 c	3.91 c	9.78 c
$S_2 – S_{100}$	6.23 b	4.22 b	10.45 b
$S_3 – S_{125}$	7.07 a	4.77 a	11.83 a
S.Em. ±	0.06	0.05	0.08
Nitrogen level (N) kg ha^{-1}			
N_1 - 90	5.67 c	4.07 b	9.74 c
N_2 - 120	6.19 b	4.25 b	10.43 b
N_3 - 150	7.30 a	4.59 a	11.89 a
S.Em. ±	0.06	0.05	0.08
Interaction (G × S × N)			
$G_1 S_1 N_1$	5.30l	3.77 f	9.08 j
$G_1 S_1 N_2$	5.79 i-k	3.79 f	9.58 h-j
$G_1 S_1 N_3$	6.57 d-f	4.02 ef	10.59 de
$G_1 S_2 N_1$	5.42 kl	4.01 ef	9.43 ij
$G_1 S_2 N_2$	6.04 g-j	4.14 d-f	10.18 e-h
$G_1 S_2 N_3$	6.67 de	4.29 b-e	10.96 d
$G_1 S_3 N_1$	5.83 h-k	4.51 b-d	10.34 e-g
$G_1 S_3 N_2$	6.38 e-g	4.63 bc	11.00 d
$G_1 S_3 N_3$	8.20 b	5.20 a	13.39 b
$G_2 S_1 N_1$	5.44 kl	3.81 f	9.25 ij
$G_2 S_1 N_2$	5.81 ik	3.99 ef	9.80 f-i
$G_2 S_1 N_3$	6.28 e-h	4.09 d-f	10.37 d-f
$G_2 S_2 N_1$	5.70 j-l	4.04 ef	9.74 g-j
$G_2 S_2 N_2$	6.19 f-i	4.21 c-f	10.40 d-f
$G_2 S_2 N_3$	7.35 c	4.64 bc	11.99 c
$G_2 S_3 N_1$	6.35 e-g	4.26 b-e	10.60 d-e
$G_2 S_3 N_2$	6.90 d	4.73 b	11.64 c
$G_2 S_3 N_3$	8.75 a	5.28 a	14.03 a
S.Em. ±	0.15	0.13	0.20

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

The treatment combination $G_2S_3N_3$ *i.e.* genotype JHO-822 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen recorded significantly higher total dry matter yield (14.03 t ha^{-1}) compared to rest of the combinations and it was followed by $G_1S_3N_3$ *i.e.* genotype OS-6 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen (13.39t ha^{-1}). Similar trend was noticed during first and second harvests (8.75 and 5.28 t ha^{-1}, respectively). During second harvest it was on par with $G_1S_3N_3$ *i.e.* genotype OS-6 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen (5.20 t ha^{-1}). However, the significantly lowest total green forage yield was recorded with $G_1S_1N_1$ *i.e.* genotype OS-6 with 75 kg ha^{-1} seed rate at 90 kg ha^{-1} nitrogen (9.08s t ha^{-1}). Similar trend was noticed during first and second harvests also.

4.3 Forage quality parameters

4.3.1 Organic matter content (cf. Table 14)

The oat genotypes differed significantly with respect to organic matter content during first and second harvests. The genotype OS-6 recorded significantly higher organic matter content (90.90% and 90.70%, respectively) over JHO-822 (90.69% and 90.50%, respectively).

With increase in level of seed rate there was linear and significant decrease in organic matter content during first and second harvests. Significantly higher organic matter content was recorded with seed rate of 75 kg per ha during first harvest (91.23%) and second harvest (91.97%). However, higher seed rate of 125 kg per ha recorded significantly lower organic matter content (90.27% and 90.10% during first and second harvests, respectively).

There was linear and significant increase in organic matter content with decrease in nitrogen level. Lower nitrogen level of 90 kg per ha recorded significantly higher organic matter content during first harvest (91.46%) and second harvest (91.31%). Significantly least organic matter content was recorded with higher nitrogen level of 150 kg per ha (89.94% and 89.67%, respectively).

Interaction effect was significant during first harvest. The organic matter content ranged from 88.45% to 91.72%. The treatment combination $G_1S_1N_1$ *i.e.*, OS-6 with 75 kg per ha seed rate at 90 kg per ha nitrogen recorded significantly higher organic matter content (91.72%). It was on par with $G_1S_2N_1$, $G_2S_1N_1$ and $G_2S_1N_2$. Significantly least organic matter content was recorded with $G_2S_3N_3$ *i.e.*, JHO-822 with 125 kg per ha seed rate at 150 kg per ha nitrogen (88.45%). During second harvest, the organic matter content ranged from 88.17% to 91.47%. The treatment combination $G_2S_1N_1$ *i.e.*, JHO-822 with 75 kg per ha seed rate at 90 kg per ha nitrogen recorded significantly higher organic matter content (91.47%), and it was on par with $G_1S_2N_1$, $G_1S_3N_1$ and $G_1S_1N_1$. Significantly lower organic matter content was recorded with $G_2S_3N_3$ *i.e.*, JHO-822 with 125 kg per ha at 150 kg per ha nitrogen (88.17%).

4.3.2 Organic matter yield (cf. Table 14)

The oat genotypes differed significantly with respect to organic matter yield during first, second and total of two harvests. The genotype JHO-822 recorded significantly higher organic matter yield (5914, 3944 and 9858 kg ha^{-1}, respectively).

Significantly higher organic matter yield was recorded with seed rate at 125 kg per ha during first harvest (6369 kg ha^{-1}), second harvest (4193 kg ha^{-1}) and total of two harvests (10562 kg ha^{-1}). However, lower seed rate of 75 kg per ha recorded significantly lower organic matter yield (5349, 3449 and 8798 kg ha^{-1}, respectively during first, second harvest and total of two harvests, respectively).

There was linear and significant increase in organic matter yield with increase in nitrogen level. Higher nitrogen level of 150 kg per ha recorded significantly higher organic matter yield during first harvest (6562 kg ha^{-1}), second harvest (4345 kg ha^{-1}) and total of two harvests (10907 kg ha^{-1}). Significantly least organic matter yield was recorded with lower nitrogen level of 90 kg per ha (5188, 3299 and 8487 kg ha^{-1}, respectively).

Interaction effect was significant irrespective of first, second or total of two harvests. The treatment combination $G_2S_3N_3$ *i.e.*, genotype JHO-822 with 125 kg per ha seed rate at 150 kg per ha nitrogen recorded significantly higher organic matter yield (7742, 5109 and 12851 kg ha^{-1}, respectively).

Table 14: Organic matter content and yield of oat genotypes as influenced by seed rate and nitrogen levels

Treatment	Organic matter				
	Content (%)		Yield (kg ha^{-1})		
	First harvest	Second harvest	First harvest	Second harvest	Total of two harvests
Genotype (G)					
G_1 – OS-6	90.90 a	90.70 a	5671 b	3580 b	9251 b
G_2 - JHO-822	90.69 b	90.50 b	5914 a	3944 a	9858 a
S.Em. ±	0.03	0.03	44	63	79
Seed rate (S) kg ha^{-1}					
S_1 – S_{75}	91.23 a	90.97 a	5349 c	3449 b	8798 c
S_2 – S_{100}	90.89 b	90.74 b	5658 b	3645 b	9302 b
S_3 – S_{125}	90.27 c	90.10 c	6369 a	4193 a	10562 a
S.Em. ±	0.03	0.04	54	77	97
Nitrogen level (N) kg ha^{-1}					
N_1 - 90	91.46 a	91.31 a	5188 c	3299 c	8487 c
N_2 - 120	90.98 b	90.83 b	5627 b	3643 b	9270 b
N_3 - 150	89.94 c	89.67 c	6562 a	4345 a	10907 a
S.Em. ±	0.03	0.04	54	77	97
Interaction (G × S × N)					
G_1 S_1 N_1	91.72 a	91.42 ab	4862 j	2833 g	7695 i
G_1 S_1 N_2	91.20 cd	90.95 cd	5279 g-j	3271 d-g	8550 gh
G_1 $S_1 N_3$	90.72 f	90.40 e	5964 de	3839 b-d	9803 cd
G_1 S_2 N_1	91.63 a	91.45 a	4968 ij	3005 fg	7972 hi
G_1 S_2 N_2	91.03 de	90.92 cd	5500 f-h	3368 d-g	8868 e-g
G_1 S_2 N_3	90.42 g	90.15 ef	6030 de	3882 b-d	9912 cd
G_1 S_3 N_1	91.30 bc	91.40 ab	5325 g-i	3434 d-g	8759 fg
G_1 S_3 N_2	90.77 ef	90.77 d	5789 ef	3691 b-e	9480 d-f
G_1 S_3 N_3	89.32 h	88.87 g	7320 b	4897 a	12216 a
G_2 S_1 N_1	91.63 a	91.47 a	4985 ij	3161 e-g	8146 g-i
G_2 S_1 N_2	91.45 ab	91.20 a-c	5311 g-i	3513 c-f	8824 e-g
G_2 S_1 N_3	90.63 fg	90.38 e	5694 e-g	4076 bc	9770 cd
G_2 S_2 N_1	91.33 bc	91.08 b-d	5206 h-j	3564 c-f	8770 fg
G_2 S_2 N_2	90.78 ef	90.78 d	5623 e-h	3781 b-e	9404 d-f
$G_2 S_2$ N_3	90.12 cd	90.03 f	6620 c	4267 b	10888 b
G_2 S_3 N_1	91.12 cd	91.03 cd	5782 f	3794 b-d	9577 e
G_2 S_3 N_2	90.65 f	90.38 e	6258 d	4233 b	10490 c
G_2 S_3 N_3	88.45 i	88.17 h	7741 a	5109 a	12851 a
S.Em. ±	0.08	0.10	133	188	238

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

Next best combination was $G_1S_3N_3$ *i.e.*, genotype OS-6 with 125 kg per ha seed rate at 150 kg per ha nitrogen (7320, 4897 and 12216 kg ha^{-1}, respectively). Significantly least organic matter yield was recorded with $G_1S_1N_1$ *i.e.*, genotype OS-6 with 75 kg per ha seed rate at 90 kg per ha nitrogen (4862, 2833 and 7695 kg ha^{-1}, respectively).

4.3.3 Crude protein content (cf. Table 15 and Fig. 4)

The genotypes did not influence the crude protein content significantly during first and second harvests. However, levels of seed rate and nitrogen and their interaction with genotypes differed significantly.

Significantly higher crude protein content was recorded with seed rate of 125 kg per ha during first harvest (7.82%) and second harvest (6.19%). It was on par with 100 kg per ha seed rate during first harvest. However, lower seed rate of 75 kg per ha recorded significantly lower crude protein content (7.55 and 5.97% during first and second harvests, respectively).

There was linear and significant increase in crude protein content with increase in nitrogen level. Higher nitrogen level of 150 kg per ha recorded significantly higher crude protein content during first harvest (7.98%) and second harvest (6.70%). Significantly least crude protein content was recorded with lower nitrogen level of 90 kg per ha (7.43% and 5.58%, respectively).

Interaction effect was significant irrespective of first or second harvests. The treatment combination $G_2S_3N_3$ *i.e.*, genotype JHO-822 with 125 kg per ha seed rate at 150 kg per ha nitrogen recorded significantly higher crude protein content (8.28% and 7.12%, respectively) and it was on par with $G_1S_3N_3$ *i.e.*, genotype OS-6 with 125 kg per ha seed rate at 150 kg per ha nitrogen (8.25% and 6.85%, respectively). Significantly least crude protein content was recorded with $G_1S_1N_1$ *i.e.*, genotype OS-6 with 75 kg per ha seed rate at 90 kg per ha nitrogen (7.43% and 5.48%, respectively).

4.3.4 Crude protein yield (cf. Table 15 and Fig. 4)

The oat genotypes differed significantly with respect to crude protein yield during first, second and total of two harvests. The genotype JHO-822 recorded significantly higher crude protein yield (505, 264 and 769 kg ha^{-1}, respectively).

During first, second and total of two harvests, significant and linear increase in crude protein yield was noticed with increase in seed rate. Significantly higher crude protein yield was recorded with seed rate of 125 kg per ha during first harvest (556 kg ha^{-1}), second harvest (287 kg ha^{-1}) and total of two harvests (843 kg ha^{-1}). However, lower seed rate of 75 kg per ha recorded significantly lower crude protein yield (444, 229 and 672 kg ha^{-1} during first, second and total of two harvests, respectively).

There was linear and significant increase in crude protein yield with increase in nitrogen level. Higher nitrogen level of 150 kg per ha recorded significantly higher crude protein yield during first harvest (585 kg ha^{-1}), second harvest (321 kg ha^{-1}) and total of two harvests (906 kg ha^{-1}). Significantly least crude protein yield was recorded with lower nitrogen level of 90 kg per ha (421, 202 and 623 kg ha^{-1}, respectively).

Interaction effect was significant for first, second or total of two harvests. The treatment combination $G_2S_3N_3$ *i.e.*, genotype JHO-822 with 125 kg per ha seed rate at 150 kg per ha nitrogen recorded significantly higher crude protein yield (724, 380 and 1104 kg ha^{-1}, respectively). It was on par with $G_1S_3N_3$ *i.e.*, genotype OS-6 with 125 kg per ha seed rate at 150 kg per ha nitrogen (378 and 1054 kg ha^{-1}, respectively during second and total of two harvests).

Significantly least crude protein yield was recorded with $G_1S_1N_1$ *i.e.*, genotype OS-6 with 75 kg per ha seed rate at 90 kg per ha nitrogen (394, 170 and 564 kg ha^{-1}, respectively).

4.3.5 Ether extract content (cf. Table 16 and Fig. 5)

The genotypes did not influence the ether extract content significantly during first and second harvests. However, levels of seed rate, nitrogen and their interaction with genotype differed significantly.

Table 15: Crude protein content and yield of oat genotypes as influenced by seed rate and nitrogen levels

Treatment	Crude protein				
	Content (%)		Yield (kg ha^{-1})		
	First harvest	Second harvest	First harvest	Second harvest	Total of two harvests
Genotype (G)					
G_1 – OS-6	7.66 a	6.04 a	481 b	242 b	722 b
G_2 - JHO-822	7.70 a	6.07 a	505 a	264 a	769 a
S.Em. ±	0.04	0.03	4	5	6
Seed rate (S) kg ha^{-1}					
S_1 – S_{75}	7.55 b	5.97 b	444 c	229 b	672 c
S_2 – S_{100}	7.67 b	5.99 b	479 b	242 b	721 b
S_3 – S_{125}	7.82 a	6.19 a	556 a	287 a	843 a
S.Em. ±	0.05	0.04	5	6	8
Nitrogen level (N) kg ha^{-1}					
N_1 - 90	7.43 c	5.58 c	421 c	202 c	623 c
N_2 - 120	7.63 b	5.88 b	472 b	236 b	708 b
N_3 - 150	7.98 a	6.70 a	585 a	321 a	906 a
S.Em. ±	0.05	0.04	5	6	8
Interaction (G × S × N)					
$G_1 S_1 N_1$	7.43 d	5.48 f	394 j	170 h	564 i
$G_1 S_1 N_2$	7.45 d	5.72 d-f	429 h-j	206 e-h	635 gh
$G_1 S_1 N_3$	7.69 b-d	6.65 bc	506 de	283 bc	789 cd
$G_1 S_2 N_1$	7.50 cd	5.60 ef	406 ij	184 gh	590 hi
$G_1 S_2 N_2$	7.58 b-d	5.86 de	458 f-g	217 e-g	675 fg
$G_1 S_2 N_3$	7.91 b	6.62 bc	528 d	285 bc	813 c
$G_1 S_3 N_1$	7.39 d	5.60 ef	431 h-j	210 e-h	641 gh
$G_1 S_3 N_2$	7.82 bc	5.95 d	498 d-f	242 c-e	741 de
$G_1 S_3 N_3$	8.25 a	6.85 ab	676 b	378 a	1054 a
$G_2 S_1 N_1$	7.38 d	5.63 ef	401 ij	195 f-h	596 hi
$G_2 S_1 N_2$	7.57 b-d	5.89 de	440 g-i	227 e-g	667 fg
$G_2 S_1 N_3$	7.83 bc	6.48 c	492 d-f	292 b	784 cd
$G_2 S_2 N_1$	7.37 d	5.51 f	420 h-j	216 e-g	635 gh
$G_2 S_2 N_2$	7.73 b-d	5.89 de	479 e-g	246 c-e	725 ef
$G_2 S_2 N_3$	7.93 b	6.48 c	583 c	307 b	889 b
$G_2 S_3 N_1$	7.50 cd	5.66 d-f	476 e-g	236 d-f	712 ef
$G_2 S_3 N_2$	7.67 b-d	5.95 d	529 d	279 b-d	808 c
$G_2 S_3 N_3$	8.28 a	7.12 a	724 a	380 a	1104 a
S.Em. ±	0.11	0.10	13	14	19

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

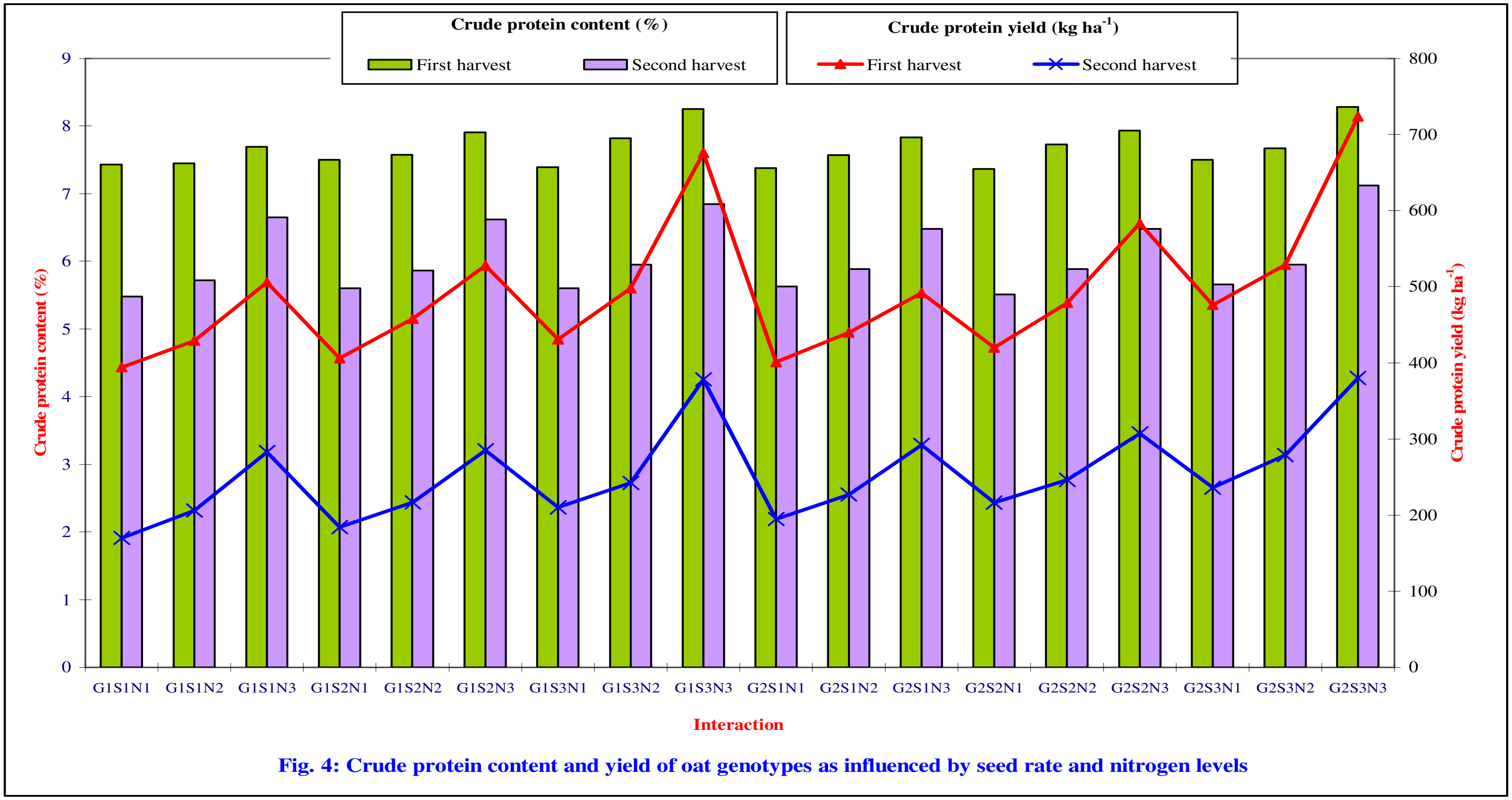

Fig. 4: Crude protein content and yield of oat genotypes as influenced by seed rate and nitrogen levels

Table 16: Ether extract content and yield of oat genotypes as influenced by seed rate and nitrogen levels

Treatment	Ether extract				
	Content (%)		Yield (kg ha^{-1})		
	First harvest	Second harvest	First harvest	Second harvest	Total of two harvests
Genotype (G)					
G_1 – OS-6	2.19 a	2.44 a	138 b	97 b	235 b
G_2 - JHO-822	2.25 a	2.44 a	148 a	107 a	255 a
S.Em. ±	0.01	0.02	1	2	3
Seed rate (S) kg ha^{-1}					
S_1 – S_{75}	2.17 b	2.40 b	128 c	91 c	219 c
S_2 – S_{100}	2.23 b	2.43 b	140 b	98 b	238 b
S_3 – S_{125}	2.25 a	2.49 a	161 a	117 a	277 a
S.Em. ±	0.02	0.02	2	2	3
Nitrogen level (N) kg ha^{-1}					
N_1 - 90	2.05 c	2.35 c	117 c	84 c	201 c
N_2 - 120	2.19 b	2.41 b	135 b	96 b	232 b
N_3 - 150	2.42 a	2.57 a	177 a	125 a	302 a
S.Em. ±	0.02	0.02	2	2	3
Interaction (G × S × N)					
G_1 S_1 N_1	1.98 e	2.33 d	105 k	71 g	176 k
G_1 S_1 N_2	2.11 e	2.36 cd	122 hi	85 e-g	207 h-j
G_1 S_1N_3	2.51 a	2.54 bc	165 d	107 b-d	272 d
G_1 S_2 N_1	2.01 e	2.35 cd	109 i-k	78 fg	187 j-k
G_1 S_2 N_2	2.15 de	2.39 cd	129 gh	89 d-g	218 gh
G_1 S_2 N_3	2.35 bc	2.47 bc	157 de	107 b-d	263 de
G_1 S_3 N_1	2.05 e	2.37 cd	119 h-j	88 d-g	207 h-j
G_1 S_3 N_2	2.16 cd	2.44 cd	138 fg	98 c-e	236 fg
G_1 S_3 N_3	2.41 ab	2.68 a	197 b	148 a	345 b
G_2 S_1 N_1	1.99 e	2.34 d	108 jk	81 e-g	190 i-k
G_2 S_1 N_2	2.13 de	2.39 cd	123 h	90 d-f	214 g-i
G_2 S_1 N_3	2.34 bc	2.45 bc	147 ef	111 bc	258 d-f
G_2 S_2 N_1	2.11 de	2.34 d	120 h-j	91 d-f	212 g-j
G_2 S_2 N_2	2.36 ab	2.41 cd	146 ef	101 c-e	247 ef
G_2 S_2 N_3	2.41 ab	2.61 ab	177 c	123 b	300 c
G_2 S_3 N_1	2.16 cd	2.35 cd	137 fg	97 c-e	234 g
G_2 S_3 N_2	2.25 cd	2.44 cd	155 de	114 bc	269 e
G_2 S_3 N_3	2.51 a	2.66 a	219 a	154 a	373 a
S.Em. ±	0.04	0.05	4	6	8

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

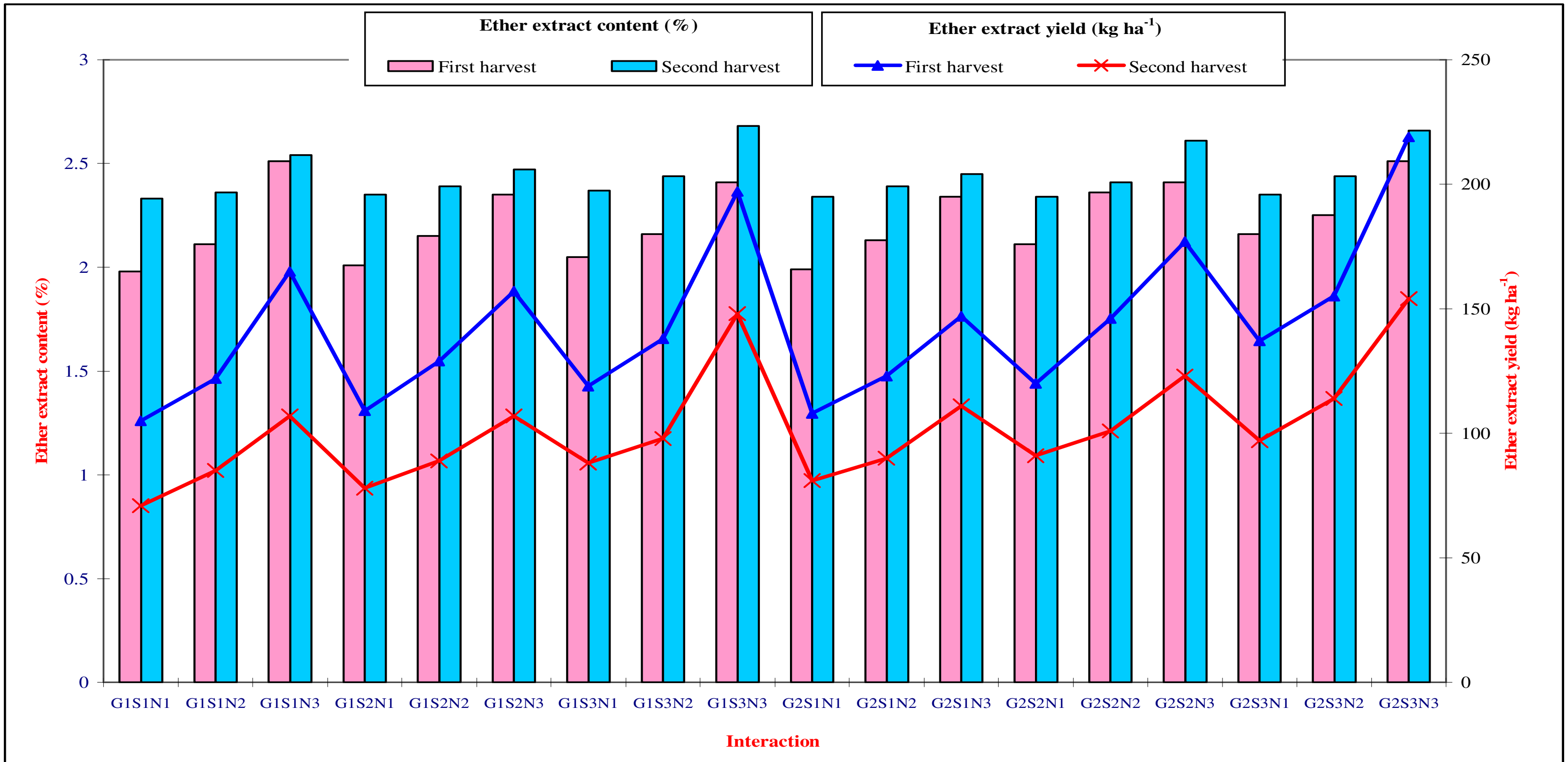

Fig. 5: Ether extract content and yield of oat genotypes as influenced by seed rate and nitrogen levels

Fig. 5: Ether extract content and yield of oat genotypes as influenced by seed rate and nitrogen levels

Significantly higher ether extract content was recorded with seed rate of 125 kg per ha during first harvest (2.25%) and second harvest (2.49%). However, lower seed rate of 75 kg per ha recorded significantly lower ether extract content (2.17% and 2.40% during first and second harvests, respectively). Seed rate of 100 and 75 kg ha^{-1} were on par.

There was linear and significant increase in ether extract content with increase in nitrogen level. Higher nitrogen level of 150 kg per ha recorded significantly higher ether extract content during first harvest (2.42%) and second harvest (2.57%). Significantly least ether extract content was recorded with lower nitrogen level of 90 kg per ha (2.05% and 2.35%, respectively).

Interaction effect was significant irrespective of first or second harvest. The treatment combination $G_2S_3N_3$ *i.e.*, genotype JHO-822 with 125 kg per ha seed rate at 150 kg per ha nitrogen recorded significantly higher ether extract content (2.51% and 2.66%, respectively) and it was on par with $G_1S_3N_3$ *i.e.*, genotype OS-6 with 125 kg per ha seed rate at 150 kg per ha nitrogen (2.41% and 2.68%, respectively). Significantly least ether extract content was recorded with $G_1S_1N_1$ *i.e.*, genotype OS-6 with 75 kg per ha seed rate at 90 kg per ha nitrogen (1.98% and 2.33%, respectively).

4.3.6 Ether extract yield (cf. Table 16 and Fig. 5)

The oat genotypes differed significantly with respect to ether extract yield during first, second and total of two harvests. The genotype JHO-822 recorded significantly higher ether extract yield (148, 107 and 255 kg ha^{-1}, respectively) over OS-6 (138, 97 and 235 kg ha^{-1}, respectively).

There was linear and significant increase in ether extract yield with increase in seed rate level during first, second and total of two harvests. Significantly higher ether extract yield was recorded with seed rate of 125 kg per ha during first harvest (161 kg ha^{-1}), second harvest (117 kg ha^{-1}) and total of two harvests (277 kg ha^{-1}). However, lower seed rate 75 kg per ha recorded significantly lower ether extract yield (128, 91 and 219 kg ha^{-1} during first, second and total of two harvests, respectively).

There was linear and significant increase in ether extract yield with increase in nitrogen level. Higher nitrogen level of 150 kg per ha recorded significantly higher ether extract yield during first, second and total of two harvests (177, 125 and 302 kg ha^{-1}, respectively). Significantly least ether extract yield was recorded with lower nitrogen level of 90 kg per ha during first, second and total of two harvests (117, 84 and 201 kg ha^{-1}, respectively).

Interaction effect was significant irrespective of first, second or total of two harvests. The treatment combination $G_2S_3N_3$ *i.e.*, genotype JHO-822 with 125 kg per ha seed rate at 150 kg per ha nitrogen recorded significantly higher ether extract yield (219, 154 and 373 kg ha^{-1}, respectively). However, it was on par with $G_1S_3N_3$ *i.e.*, genotype OS-6 with 125 kg per ha seed rate at 150 kg per ha nitrogen during second harvest (148 kg ha^{-1}) followed by $G_1S_3N_3$ during first harvest and total of two harvests. Significantly least ether extract yield was recorded with $G_1S_1N_1$ *i.e.*, genotype OS-6 with 75 kg per ha seed rate at 90 kg per ha nitrogen (105, 71 and 176 kg ha^{-1}, respectively).

4.3.7 Crude fibre content (cf. Table 17 and Fig. 6)

The genotype did not influence the crude fibre content significantly during first and second harvests. However, levels of seed rate, nitrogen and their interaction with genotype differed significantly.

During first and second harvest, significantly lower crude fibre content was recorded with seed rate 125 kg per ha during first and second harvests (20.00% and 29.43%, respectively). However, seed rate of 100 kg per ha recorded significantly higher crude fibre content during first harvest (21.27%) and it was on par with 75 kg per ha seed rate. Seed rate of 75 kg per ha recorded significantly higher crude fibre content during second harvest (30.60%) and it was on par with 100 kg per ha seed rate.

Table 17: Crude fibre content and yield of oat genotypes as influenced by seed rate and nitrogen levels

Treatment	Crude fibre				
	Content (%)		Yield (kg ha^{-1})		
	First harvest	Second harvest	First harvest	Second harvest	Total of two harvests
Genotype (G)					
G_1 – OS-6	20.61 a	29.92 a	1275 b	1172 b	2447 b
G_2 - JHO-822	20.67 a	30.05 a	1338 a	1306 a	2644 a
S.Em. ±	0.21	0.28	13	24	26
Seed rate (S) kg ha^{-1}					
S_1 – S_{75}	20.65 ab	30.60 a	1206 c	1155 b	2361 c
S_2 – S_{100}	21.27 a	29.92 ab	1316 b	1196 b	2512 b
S_3 – S_{125}	20.00 b	29.43 b	1398 a	1364 a	2762 a
S.Em. ±	0.26	0.34	16	29	31
Nitrogen level (N) kg ha^{-1}					
N_1 - 90	22.40 a	31.43 a	1270 b	1133 b	2403 b
N_2 - 120	20.56 b	30.03 b	1271 b	1202 b	2473 b
N_3 - 150	18.97 c	28.49 c	1379 a	1380 a	2759 a
S.Em. ±	0.26	0.34	16	29	31
Interaction (G × S × N)					
G_1 S_1 N_1	22.52 a-c	31.91 a	1188 f	992 f	2180 i
G_1 S_1 N_2	20.15 d-f	30.52 a-d	1165 f	1089 d-f	2254 hi
G_1 S_1N_3	19.64 d-g	29.56 a-e	1292 c-f	1258 c-e	2550 ef
G_1 S_2 N_1	23.15 ab	31.38 a-c	1260 c-f	1020 ef	2280 g-i
G_1 S_2 N_2	20.51 c-e	29.86 a-d	1236 c-f	1105 d-f	2341 f-i
G_1 S_2 N_3	19.30 e-g	28.56 c-e	1283 c-f	1225 c-f	2507 e-h
G_1 S_3 N_1	22.31 a-c	31.55 a-b	1300 c-f	1189 c-f	2489 e-h
G_1 S_3 N_2	19.56 d-g	28.91 b-e	1249 c-f	1176 c-f	2425 e-i
G_1 S_3 N_3	18.34 fg	27.04 e	1503 a	1491 ab	2994 ab
G_2 S_1 N_1	21.56 a-d	31.55 ab	1175 f	1087 d-f	2262 g-i
G_2 S_1 N_2	20.81 c-e	31.24 b-d	1207 ef	1204 c-f	2412 e-i
G_2 S_1 N_3	19.24 e-g	28.83 b-e	1211 d-f	1302 b-d	2514 e-g
G_2 S_2 N_1	23.51 a	31.34 a-c	1343 b-d	1225 c-f	2568 d-f
G_2 S_2 N_2	21.52 a-d	29.86 a-d	1331 b-e	1243 c-e	2574 d-f
G_2 S_2 N_3	19.64 d-g	28.56 d-e	1442 ab	1361 bc	2803 b-d
G_2 S_3 N_1	21.34 b-e	30.86 a-d	1353 bc	1286 b-d	2640 c-e
G_2 S_3 N_2	20.81 c-e	29.83 a-d	1435 ab	1397 bc	2833 bc
G_2 S_3 N_3	17.64 g	28.41 de	1544 a	1644 a	3188 a
S.Em. ±	0.64	0.83	40	71	77

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT ($P = 0.05$)

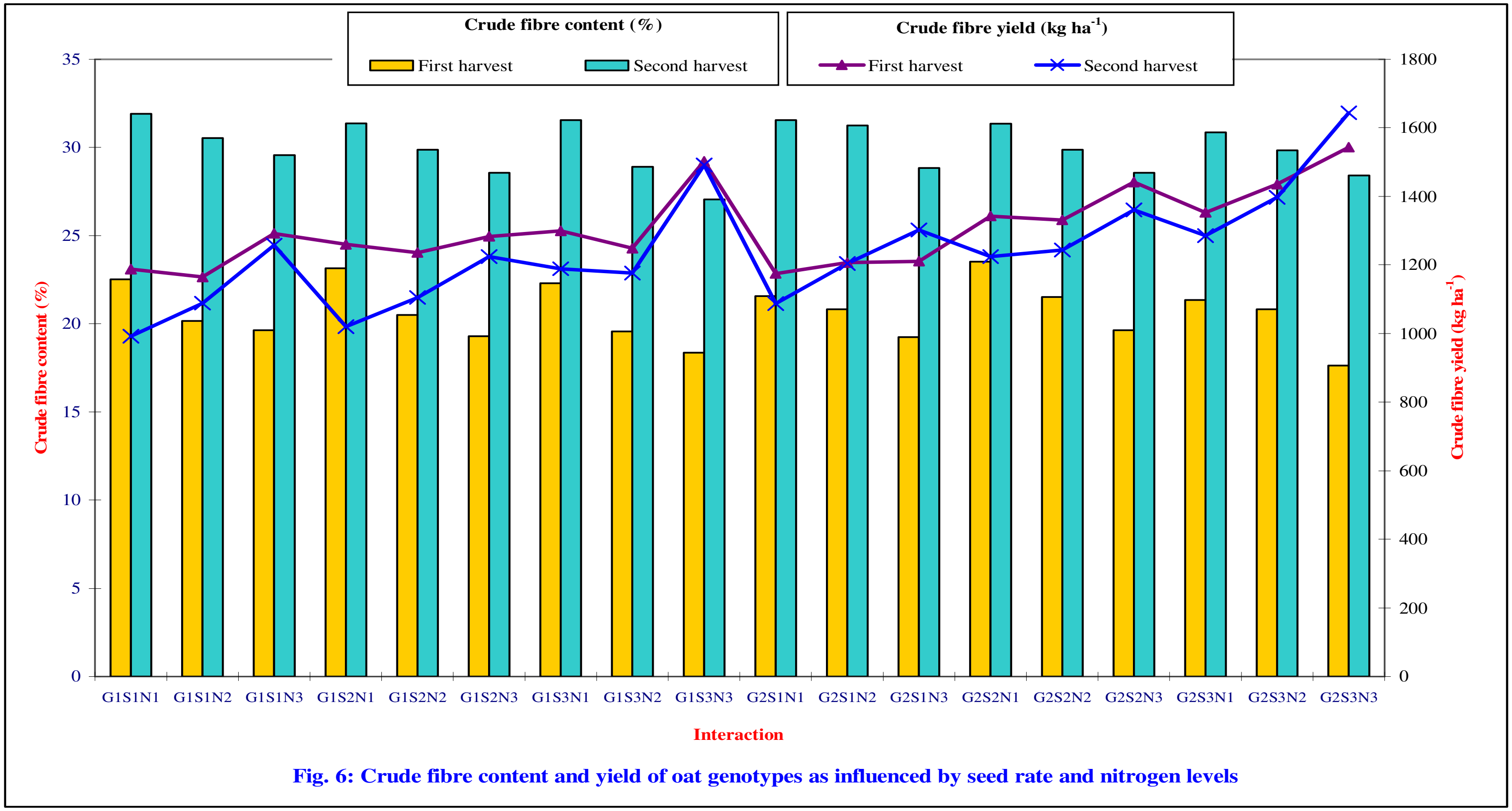

Fig. 6: Crude fibre content and yield of oat genotypes as influenced by seed rate and nitrogen levels

There was linear and significant decrease in crude fibre content with increase in nitrogen level. Higher nitrogen level of 150 kg per ha recorded significantly lower crude fibre content during first and second harvests (18.97% and 28.49%, respectively). Significantly higher crude fibre content was recorded with lower nitrogen level of 90 kg per ha (22.40% and 31.43%, respectively).

Interaction effect was significant during both the harvests. The treatment combination $G_2S_3N_3$ *i.e.*, JHO-822 with 125 kg per ha seed rate at 150 kg per ha nitrogen recorded significantly lower crude fibre content during first harvest (17.64%). It was on par with $G_1S_3N_3$ *i.e.*, genotype OS-6 with 125 kg per ha seed rate at 150 kg per ha nitrogen (18.34%), $G_1S_2N_3$, $G_1S_2N_3$, $G_1S_3N_2$, $G_2S_1N_3$ and $G_2S_2N_3$. During second harvest, the treatment combination $G_1S_3N_3$ *i.e.*, genotype OS-6 with 125 kg per ha seed rate at 150 kg per ha nitrogen recorded significantly lower crude fibre content (27.04%). It was on par with $G_2S_3N_3$ *i.e.*, JHO-822 with 125 kg per ha seed rate at 150 kg per ha nitrogen (28.41%), $G_1S_1N_3$, $G_1S_2N_3$, $G_1S_3N_2$, $G_2S_1N_3$ and $G_2S_2N_3$. Significantly higher crude fibre content was recorded with $G_2S_2N_1$ *i.e.*, genotype JHO-822 with 100 kg per ha seed rate at 90 kg per ha nitrogen (23.51%) during first harvest. During second harvest, significantly higher crude fibre content was recorded with $G_1S_1N_1$ *i.e.*, genotype OS-6 with 75 kg per ha seed rate at 90 kg per ha nitrogen (31.91%).

4.3.8 Crude fibre yield (cf. Table 17 and Fig. 6)

The oat genotypes differed significantly with respect to crude fibre yield during first, second and total of two harvests. The genotype JHO-822 recorded significantly higher crude fibre yield (1338, 1306 and 2644 kg ha^{-1}, respectively) over OS-6 (1275, 1172 and 2447 kg ha^{-1}, respectively).

There was linear increase in crude fibre yield with increase in seed rate. During first, second and total of two harvests, significantly higher crude fibre yield was recorded with seed rate of 125 kg per ha during first, second and total of two harvests (1398, 1364 and 2762 kg ha^{-1}, respectively). However, lower seed rate of 75 kg per ha recorded significantly lower crude fibre yield (1206, 1155 and 2361 kg ha^{-1} during first, second and total of two harvests, respectively).

There was significant increase in crude fibre yield with increase in nitrogen level. Nitrogen level of 150 kg per ha recorded significantly higher crude fibre yield during first, second and total of two harvests (1379, 1380 and 2759 kg ha^{-1}, respectively). Significantly least crude fibre yield was recorded with lower nitrogen level of 90 kg per ha (1270, 1133 and 2403 kg ha^{-1}, respectively), which was on par with 120 kg per ha nitrogen.

Interaction effect was significant irrespective of first, second and total of two harvests. The treatment combination $G_2S_3N_3$ *i.e.*, genotype JHO-822 with 125 kg per ha seed rate of 150 kg per ha nitrogen recorded significantly higher crude fibre yield (1544, 1644 and 3188 kg ha^{-1}, respectively). It was on par with $G_1S_3N_3$ *i.e.*, genotype OS-6 with 125 kg per ha seed rate at 150 kg per ha nitrogen (1503, 1491 and 2994 kg ha^{-1}, respectively during first, second and total of two harvests). Significantly least crude fibre yield was recorded with $G_1S_1N_1$ *i.e.*, genotype OS-6 with 75 kg per ha seed rate at 90 kg per ha nitrogen (1188, 992 and 2180 kg ha^{-1}, respectively).

4.3.9 Total ash content (cf. Table 18 and Fig. 7)

The oat genotypes differed significantly with respect to total ash content during first and second harvests. The genotype JHO-822 recorded significantly higher total ash content (9.31% and 9.50%, respectively) over OS-6 (9.10% and 9.30%, respectively).

During first and second harvests, there was linear and significant increase in total ash content with increase in seed rate. Significantly higher total ash content was recorded with seed rate of 125 kg per ha during first harvest (9.73%) and second harvest (9.90%). However, lower seed rate of 75 kg per ha recorded significantly lower total ash content (8.78% and 9.03% during first and second harvests, respectively).

Table 18: Total ash content and yield of oat genotypes as influenced by seed rate and nitrogen levels

Treatment	Total ash				
	Content (%)		Yield (kg ha^{-1})		
	First harvest	Second harvest	First harvest	Second harvest	Total of two harvests
Genotype (G)					
G_1 – OS-6	9.10 b	9.30 b	574 b	373 b	947 b
G_2 - JHO-822	9.31 a	9.50 a	617 a	420 a	1037 a
S.Em. ±	0.03	0.03	5	7	8
Seed rate (S) kg ha^{-1}					
S_1 – S_{75}	8.78 c	9.03 c	516 c	345 c	861 c
S_2 – S_{100}	9.11 b	9.26 b	571 b	375 b	946 b
S_3 – S_{125}	9.73 a	9.90 a	699 a	470 a	1169 a
S.Em. ±	0.03	0.04	6	8	10
Nitrogen level (N) kg ha^{-1}					
N_1 - 90	8.54 c	8.69 c	486 c	315 c	801 c
N_2 - 120	9.02 b	9.17 b	559 b	368 b	927 b
N_3 - 150	10.06 a	10.33 a	742 a	506 a	1248 a
S.Em. ±	0.03	0.04	6	8	10
Interaction (G × S × N)					
G_1 S_1 N_1	8.28 j	8.58 g	439 i	266 j	705 j
G_1 S_1 N_2	8.80 fg	9.05 ef	509 g	325 g-j	835 i
G_1 S_1N_3	9.28 e	9.60 d	610 de	408 d-f	1018 ef
G_1 S_2 N_1	8.37 ij	8.55 g	454 hi	281 ij	735 j
G_1 S_2 N_2	8.97 f	9.08 ef	542 fg	336 g-i	878 hi
G_1 S_2 N_3	9.58 d	9.85 c	639 d	424 c-e	1064 de
G_1 S_3 N_1	8.70 gh	8.60 g	508 g	324 g-j	831 i
G_1 S_3 N_2	9.23 e	9.23 e	589 ef	375 e-g	964 fg
G_1 S_3 N_3	10.68 b	11.13 b	876 b	613 b	1489 b
G_2 S_1 N_1	8.37 ij	8.53 g	455 hi	295 h-j	750 j
G_2 S_1 N_2	8.55 hi	8.80 fg	497 gh	340 g-i	836 i
G_2 S_1 N_3	9.37 de	9.62 d	588 ef	434 c-e	1022 d-e
G_2 S_2 N_1	8.67 gh	8.92 ef	494 gh	349 f-h	843 i
G_2 S_2 N_2	9.22 e	9.22 e	571 ef	384 e-g	955 fg
G_2 S_2 N_3	9.88 c	9.97 c	726 c	473 c	1199 c
G_2 S_3 N_1	8.88 fg	8.97 ef	564 ef	374 e-g	938 gh
G_2 S_3 N_2	9.35 de	9.62 d	646 d	451 cd	1096 d
G_2 S_3 N_3	11.55 a	11.83 a	1011 a	686 a	1697 a
S.Em. ±	0.08	0.10	16	20	25

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

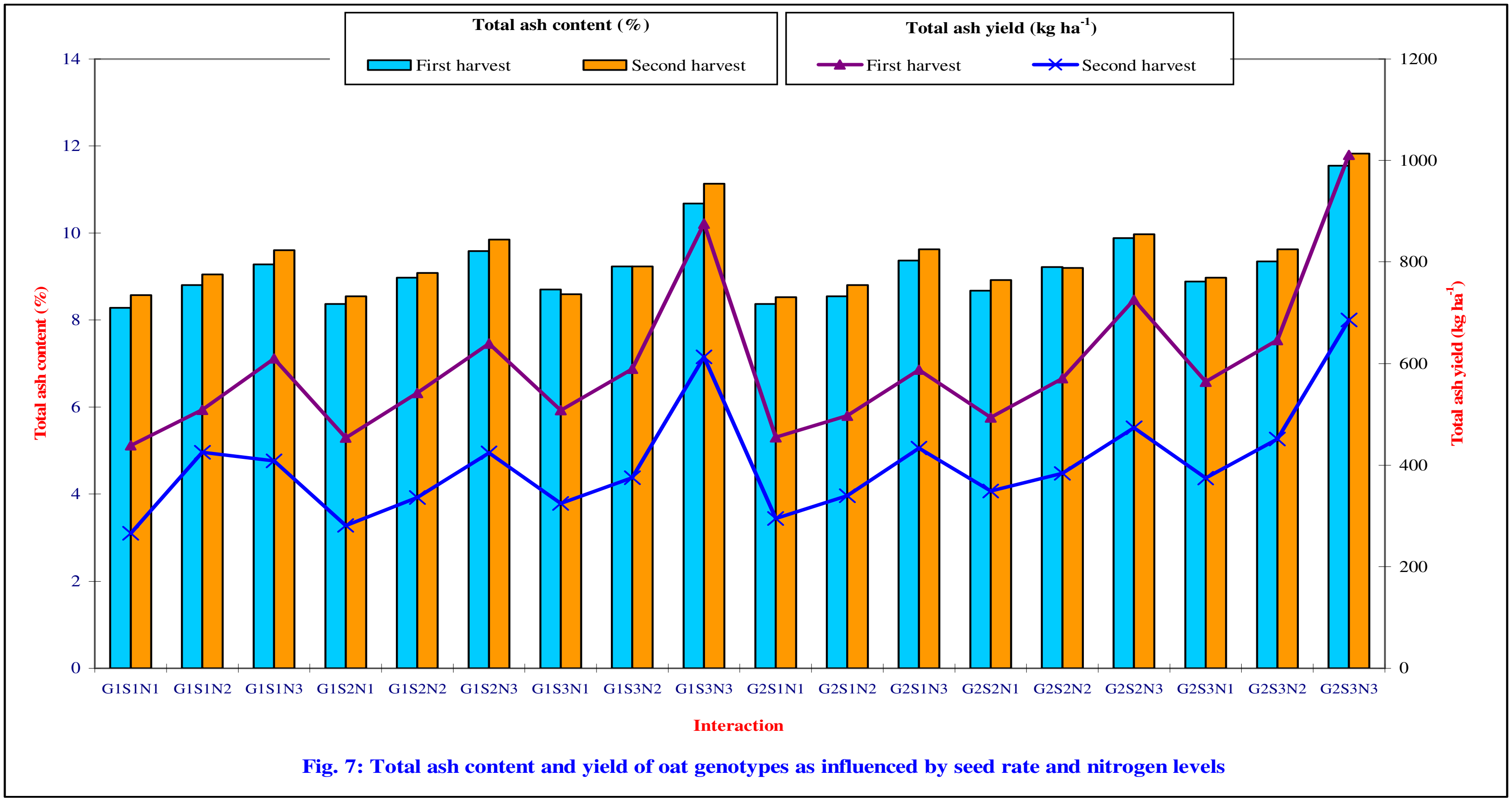

Fig. 7: Total ash content and yield of oat genotypes as influenced by seed rate and nitrogen levels

There was linear and significant increase in total ash content with increase in nitrogen level. Higher nitrogen level of 150 kg per ha recorded significantly higher total ash content during first harvest (10.06%) and second harvest (10.33%). Significantly least total ash content was recorded with lower nitrogen level of 90 kg per ha (8.54% and 8.69%, respectively).

Interaction effect was significant irrespective of first or second harvest. The treatment combination $G_2S_3N_3$ *i.e.*, genotype JHO-822 with 125 kg per ha seed rate at 150 kg per ha nitrogen recorded significantly higher total ash content (11.55% and 11.83%, respectively) over rest of the combinations. Next best combination for total ash content was $G_1S_3N_3$ *i.e.*, OS-6 with 125 kg per ha seed rate at 150 kg per ha nitrogen (10.68% and 11.13%, respectively). Significantly least total ash content was recorded with $G_1S_1N_1$ *i.e.*, genotype OS-6 with 75 kg per ha seed rate at 90 kg per ha nitrogen (8.28% and 8.58%, respectively).

4.3.10 Total ash yield (cf. Table 18 and Fig. 7)

The oat genotypes differed significantly with respect to total ash yield during first, second and total of two harvests. The genotype JHO-822 recorded significantly higher total ash yield (617, 420 and 1037 kg ha^{-1}, respectively) over OS-6 (574, 373 and 947 kg/ha, respectively).

The total ash yield increased linearly and significantly with increase in seed rate during first, second and total of two harvests. Significantly higher total ash yield was recorded with seed rate of 125 kg per ha during first harvest (699 kg/ha), second harvest (470 kg ha^{-1}) and total of two harvests (1169 kg ha^{-1}). However, lower seed rate of 75 kg per ha recorded significantly lower total ash yield (516, 345 and 861 kg/ha during first, second and total of two harvests, respectively).

There was linear and significant increase in total ash yield with increase in nitrogen level. Higher nitrogen level of 150 kg per ha recorded significantly higher total ash yield during first harvest (742 kg ha^{-1}), second harvest (506 kg ha^{-1}) and total of two harvest (1248 kg ha^{-1}). Significantly least total ash yield was recorded with lower nitrogen level of 90 kg per ha (486, 315 and 801 kg ha^{-1}, respectively).

Interaction effect was significant irrespective of first, second or total of two harvests. The treatment combination $G_2S_3N_3$ *i.e.*, genotype JHO-822 with 125 kg per ha seed rate at 150 kg per ha nitrogen recorded significantly higher total ash yield (1011, 686 and 1697 kg ha^{-1}, respectively). Next best combination for total ash yield was $G_1S_3N_3$ *i.e.*, genotype OS-6 with 125 kg per ha seed rate at 150 kg per ha nitrogen (876, 613 and 1489 kg ha^{-1}, respectively). Significantly least total ash yield was recorded with $G_1S_1N_1$ *i.e.*, genotype OS-6 with 75 kg per ha seed rate at 90 kg per ha nitrogen (439, 266 and 705 kg ha^{-1}, respectively).

4.3.11 Nitrogen free extract content (cf. Table 19)

The genotypes differed significantly for nitrogen free extract content during first harvest. The genotype OS-6 (60.31%) recorded significantly higher nitrogen free extract content over JHO-822 (59.39%). However, during second harvest, genotypes did not influence the nitrogen free extract content.

During first harvest, significantly higher nitrogen free extract content was recorded with seed rate of 75 kg per ha (60.49%) over rest of the seed rates significantly least nitrogen free extract content was recorded with seed rate of 125 kg per ha (59.60%). However, 100 and 125 kg ha^{-1} seed rates were on par. During second harvest, seed rate did not influence the nitrogen free extract content.

There was significant increase in nitrogen free extract content with nitrogen level of 120 kg per ha (60.42%) during first harvest. It was on par with 90 kg per ha nitrogen level (59.94%). Significantly least nitrogen free extract content was recorded with nitrogen level of 150 kg per ha (59.19%). During second harvest, nitrogen free extract content did not differ significantly with nitrogen levels. Interaction effect was significant irrespective of first or second harvests. The treatment combination $G_1S_3N_2$ *i.e.*, genotype OS-6 with 125 kg per ha seed rate at 120 kg per ha nitrogen recorded significantly higher nitrogen free extract content (61.23% and 53.47%, during first and second harvest respectively) over rest of the combinations except, $G_1S_3N_3$, $G_2S_2N_1$, $G_2S_2N_2$ and $G_2S_2N_3$ during first harvest.

Table 19: Nitrogen free extract content and yield of oat genotypes as influenced by seed rate and nitrogen levels

Treatment	Nitrogen free extract				
	Content (%)		Yield (kg ha^{-1})		
	First harvest	Second harvest	First harvest	Second harvest	Total of two harvests
Genotype (G)					
G_1 – OS-6	60.31 a	52.31 a	3762 b	2070 b	5832 b
G_2 - JHO-822	59.39 b	51.94 a	3873 a	2264 a	6137 a
S.Em. ±	0.22	0.30	35	37	55
Seed rate (S) kg ha^{-1}					
S_1 – S_{75}	60.49 a	52.00 a	3547 c	1974 c	5521 c
S_2 – S_{100}	59.45 b	52.39 a	3702 b	2108 b	5810 b
S_3 – S_{125}	59.60 b	51.99 a	4203 a	2419 a	6623 a
S.Em. ±	0.26	0.37	43	45	67
Nitrogen level (N) kg ha^{-1}					
N_1 - 90	59.94 ab	51.95 a	3400 c	1879 c	5279 c
N_2 - 120	60.42 a	52.52 a	3737 b	2108 b	5845 b
N_3 - 150	59.19 b	51.91 a	4316 a	2514 a	6830 a
S.Em. ±	0.26	0.37	43	45	67
Interaction (G × S × N)					
$G_1 S_1 N_1$	60.45 a-c	51.70 ab	3209 j	1601 g	4811 i
$G_1 S_1 N_2$	61.54 a	52.36 ab	3564 f-i	1891 e-g	5455 gh
$G_1 S_1 N_3$	59.87 a-d	51.65 ab	3936 c-e	2191 b-e	6127 c-e
$G_1 S_2 N_1$	59.97 a-d	52.12 ab	3245 ij	1723 fg	4968 hi
$G_1 S_2 N_2$	61.23 a	52.81 ab	3703 d-g	1958 d-f	5660 e-g
$G_1 S_2 N_3$	59.97 a-d	52.50 ab	4003 b-d	2266 b-d	6269 cd
$G_1 S_3 N_1$	59.86 a-d	51.88 ab	3493 g-j	1946 d-g	5438 gh
$G_1 S_3 N_2$	61.23 a	53.47 a	3903 c-f	2174 b-e	6077 c-e
$G_1 S_3 N_3$	58.65 b-d	52.30 ab	4806 a	2880 a	7686 a
$G_2 S_1 N_1$	60.71 ab	51.95 ab	3301 h-j	1798 fg	5099 hi
$G_2 S_1 N_2$	60.41 a-c	51.68 ab	3510 g-j	1991 d-f	5501 f-h
$G_2 S_1 N_3$	59.96 a-d	52.63 ab	3764 c-g	2370 bc	6134 c-e
$G_2 S_2 N_1$	58.31 cd	51.89 ab	3321 h-j	2032 c-f	5353 gh
$G_2 S_2 N_2$	58.65 b-d	52.63 ab	3635 e-h	2192 b-e	5826 d-g
$G_2 S_2 N_3$	58.59 b-d	52.40 ab	4306 b	2476 b	6782 b
$G_2 S_3 N_1$	60.33 a-c	52.17 ab	3829 c-g	2175 b-e	6004 d-f
$G_2 S_3 N_2$	59.46 a-d	52.17 ab	4106 bc	2443 b	6549 bc
$G_2 S_3 N_3$	58.10 d	49.98 b	5084 a	2898 a	7982 a
S.Em. ±	0.65	0.91	106	110	165

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

During second harvest, it was on par with rest of the combinations except $G_2S_3N_3$ (49.98%). Significantly least nitrogen free extract content was recorded with $G_2S_3N_3$ *i.e.*, genotype JHO-822 with 125 kg per ha seed rate at 150 kg per ha nitrogen (58.10% and 49.98% during first and second harvest, respectively).

4.3.12 Nitrogen free extract yield (cf. Table 19)

The oat genotype differed significantly with respect to nitrogen free extract yield during first, second and total of two harvests. The genotype JHO-822 recorded significantly higher nitrogen free extract yield (3873, 2264 and 6137 kg ha^{-1}, respectively) over OS-6 (3762, 2070 and 5832 kg ha^{-1}, respectively).

There was linear and significant increase in nitrogen free extract yield with increasing level of seed rate during first, second and total of two harvests. Significantly higher nitrogen free extract yield was recorded with seed rate of 125 kg per ha during first, second and total of two harvests (4203, 2419 and 6623 kg ha^{-1}, respectively). However, lower seed rate 75 kg per ha recorded significantly lower nitrogen free extract yield (3547, 1974 and 5521 kg ha^{-1} during first, second and total of two harvests, respectively).

There was linear and significant increase in nitrogen free extract yield with increase in nitrogen level. nitrogen level of 150 kg per ha recorded significantly higher nitrogen free extract yield during first, second and total of two harvests (4316, 2514 and 6830 kg ha^{-1}, respectively). Significantly least nitrogen free extract yield was recorded with lower nitrogen level of 90 kg per ha (3400, 1879 and 5279 kg ha^{-1}, respectively).

Interaction effect was significant for first, second or total of two harvests. The treatment combination $G_2S_3N_3$ *i.e.*, genotype JHO-822 with 125 kg per ha seed rate at 150 kg per ha nitrogen recorded significantly higher nitrogen free extract yield (5084, 2898 and 7982 kg ha^{-1}, respectively). It was on par with $G_1S_3N_3$ *i.e.*, genotype OS-6 with 125 kg per ha seed rate at 150 kg per ha nitrogen (4806, 2880 and 7686 kg ha^{-1}, respectively during first, second and total of two harvests). Significantly least nitrogen free extract yield was recorded with $G_1S_1N_1$ *i.e.*, genotype OS-6 with 75 kg per ha seed rate at 90 kg per ha nitrogen (3209, 1601 and 4811 kg ha^{-1}, respectively).

4.3.13 Total carbohydrate content (cf. Table 20)

The genotypes differed significantly with respect to total carbohydrate content during both the harvests. Genotype OS-6 recorded significantly higher total carbohydrate (80.92% and 82.23% during first and second harvest respectively) over JHO-822 (80.06% and 81.99% respectively).

During first and second harvests, there was linear and significantly decrease in total carbohydrate content with increase in seed rate. Significantly higher total carbohydrate content was recorded with seed rate of 75 kg per ha during first and second harvests (81.14% and 82.59%, respectively). However, higher seed rate of 125 kg per ha recorded significantly lower total carbohydrate content (79.60% and 81.42%, respectively).

There was linear and significant decrease in total carbohydrate content with increase in nitrogen level. nitrogen at 90 kg per ha recorded significantly higher total carbohydrate content during first and second harvests (82.34% and 83.38%, respectively). Significantly least total carbohydrate content was recorded with higher nitrogen level of 150 kg per ha (78.15% and 80.40%, respectively).

Interaction effect was significant during both the harvests. The treatment combination $G_1S_1N_1$ *i.e.*, genotype OS-6 with 75 kg per ha seed rate at 90 kg per ha nitrogen recorded significantly higher total carbohydrate content (82.97% and 83.60%, respectively). It was on par with $G_1S_2N_1$ *i.e.*, genotype OS-6 with 100 kg per ha seed rate at 90 kg per ha nitrogen (83.12% and 83.50% during first and second harvests, respectively). Significantly least total carbohydrate content was recorded with $G_2S_3N_3$ *i.e.*, genotype JHO-822 with 125 kg per ha seed rate at 150 kg per ha nitrogen (75.74% and 78.39%, respectively).

Table 20: Total carbohydrates content and yield of oat genotypes as influenced by seed rate and nitrogen levels

Treatment	Total carbohydrates				
	Content (%)		Yield (kg ha^{-1})		
	First harvest	Second harvest	First harvest	Second harvest	Total of two harvests
Genotype (G)					
G_1 – OS-6	80.92 a	82.23 a	5037 b	3242 b	8279 b
G_2 - JHO-822	80.06 b	81.99 b	5211 a	3569 a	8780 a
S.Em. ±	0.07	0.05	39	56	70
Seed rate (S) kg ha^{-1}					
S_1 – S_{75}	81.14 a	82.59 a	4754 c	3129 b	7883 c
S_2 – S_{100}	80.72 b	82.31 b	5018 b	3304 b	8322 b
S_3 – S_{125}	79.60 c	81.42 c	5601 a	3783 a	9384 a
S.Em. ±	0.09	0.07	48	69	86
Nitrogen level (N) kg ha^{-1}					
N_1 - 90	82.34 a	83.38 a	4670 c	3012 c	7682 c
N_2 - 120	80.98 b	82.55 b	5007 b	3311 b	8318 b
N_3 - 150	78.15 c	80.40 c	5695 a	3894 a	9589 a
S.Em. ±	0.09	0.07	48	69	86
Interaction (G × S × N)					
G_1 S_1 N_1	82.97 a	83.60 a	4398 h	2592 g	6990 i
G_1 S_1 N_2	81.69 bc	82.87 c-f	4729 f-h	2980 d-g	7709 gh
G_1 $S_1 N_3$	79.51 f	81.21 h	5227 cd	3449 b-d	8676 de
G_1 S_2 N_1	83.12 a	83.50 ab	4505 gh	2743 fg	7248 hi
G_1 S_2 N_2	81.74 bc	82.66 d-f	4939 d-f	3062 d-g	8001 e-g
G_1 S_2 N_3	79.26 j	81.06 h	5286 cd	3491 b-d	8776 cd
G_1 S_3 N_1	82.17 b	83.43 a-c	4793 e-g	3135 c-g	7927 f-h
G_1 S_3 N_2	80.79 de	82.38 fg	5152 de	3350 b-e	8503 d-f
G_1 S_3 N_3	76.99 h	79.34 i	6309 a	4371 a	10680 a
G_2 S_1 N_1	82.27 b	83.50 ab	4476 gh	2885 e-g	7361 g-i
G_2 S_1 N_2	81.22 cd	82.92 c-f	4717 f-h	3196 c-f	7913 f-h
G_2 S_1 N_3	79.20 f	81.46 h	4975 d-f	3673 bc	8648 de
G_2 S_2 N_1	81.82 bc	83.23 a-d	4664 f-h	3257 c-f	7921 f-h
G_2 S_2 N_2	80.17 e	82.48 ef	4966 d-f	3434 b-e	8400 d-f
G_2 S_2 N_3	78.23 g	80.95 h	5748 b	3837 b	9585 b
G_2 S_3 N_1	81.67 bc	83.03 b-e	5183 cd	3461 b-d	8643 de
G_2 S_3 N_2	80.27 e	81.99 g	5541 bc	3840 b	9382 bc
G_2 S_3 N_3	75.74 j	78.39 j	6628 a	4542 a	11170 a
S.Em. ±	0.21	0.16	117	168	211

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

4.3.14 Total carbohydrate yield (cf. Table 20)

The oat genotypes differed significantly with respect to total carbohydrate yield during first, second and total of two harvests. The genotype JHO-822 recorded significantly higher total carbohydrate yield (5211, 3569 and 8780 kg ha^{-1}, respectively) over OS-6 (5037, 3242 and 8279 kg ha^{-1}, respectively).

Linear increase in total carbohydrate yield was observed with increase in seed rate during both the harvests and their total. During first, second and total of two harvests, significantly higher total carbohydrate yield was rerecorded with seed rate of 125 kg per ha (5601, 3783 and 9384 kg ha^{-1}, respectively). However, lower seed rate of 75 kg per ha recorded significantly lower total carbohydrate yield during first, second and total of two harvests (4754, 3129 and 7883 kg ha^{-1}, respectively).

There was linear and significant increase in total carbohydrate yield with increase in nitrogen level. Higher nitrogen level of 150 kg per ha recorded significantly higher total carbohydrate yield during first, second and total of two harvests (5695, 3894 and 9589 kg ha^{-1}, respectively). Significantly least total carbohydrate yield was recorded with lower nitrogen level of 90 kg per ha (4670, 3012 and 7682 kg ha^{-1}, respectively).

Interaction effect was significant during first, second and total of two harvests. The treatment combination $G_2S_3N_3$ *i.e.*, genotype JHO-822 with 125 kg per ha seed rate at 150 kg per ha nitrogen recorded significantly higher total carbohydrate yield (6628, 4542 and 11170 kg ha^{-1}, respectively). It was on par with $G_1S_3N_3$ *i.e.*, genotype OS-6 with 125 kg per ha seed rate at 150 kg per ha nitrogen (6309, 4371 and 10680 kg ha^{-1}, respectively). Significantly least total carbohydrate yield was recorded with $G_1S_1N_1$ *i.e.*, genotype OS-6 with 75 kg per ha seed rate at 90 kg per ha nitrogen (4398, 2592 and 6990 kg ha^{-1}, respectively).

4.4 Nitrogen analysis

4.4.1 Plant nitrogen content (cf. Table 21)

The genotype JHO-822 recorded significantly higher plant nitrogen content during first harvest and mean (1.34 and 1.16% respectively) over OS-6. However, during second harvest genotypes did not differ significantly.

Significantly higher plant nitrogen content was recorded with seed rate of 125 kg per ha during first harvest (1.35%), second harvest (0.99%) and mean (1.17%) over rest of the seed rates. However, seed rate of 75 kg per ha was on par with 100 kg par ha seed rate.

There was linear and significant increase in plant nitrogen content with increase in nitrogen level. Higher nitrogen level of 150 kg per ha recorded significantly higher plant nitrogen content during first harvest (1.50%), second harvest (1.07%) and mean (1.29%). Significantly least plant nitrogen content was recorded with lower nitrogen level of 90 kg per ha (1.13, 0.89 and 1.01%, respectively during first harvest, second harvest and mean of two harvests, respectively).

Interaction effect was significant during first harvest, second harvest and mean. There was linear increase in plant nitrogen content with increase in nitrogen level irrespective of genotype and seed rate. The treatment combination $G_2S_3N_3$ *i.e.*, genotype JHO-822 with 125 kg per ha seed rate at 150 kg per ha nitrogen recorded significantly higher plant nitrogen content (1.63, 1.14 and 1.39%, respectively) over rest of the interactions except $G_1S_3N_3$. It was on par with $G_1S_3N_3$ *i.e.*, genotype OS-6 with 125 kg per ha seed rate at 150 kg per ha nitrogen (1.59, 1.10 and 1.34, respectively during first, second harvests and mean). Significantly least plant nitrogen content was recorded with $G_1S_1N_1$ *i.e.*, genotype OS-6 with 75 kg per ha seed rate at 90 kg per ha nitrogen (1.04, 0.88 and 0.96%, respectively).

4.4.2 Nitrogen uptake (cf. Table 22)

The genotype JHO-822 recorded significantly higher nitrogen uptake (87.6, 42.8 and 130.4 kg ha^{-1} respectively) during first harvest, second harvest and for total over OS-6.

Table 21: Plant nitrogen content (%) of oat genotypes as influenced by seed rate and nitrogen levels

Treatment	First harvest	Second harvest	Mean
Genotypes (G)			
G_1 – OS-6	1.25 b	0.97 a	1.11 b
G_2 - JHO-822	1.34 a	0.97 a	1.16 a
S.Em. ±	0.01	0.01	0.01
Seed rate (S) kg ha^{-1}			
S_1 – S_{75}	1.27 b	0.96 b	1.11 b
S_2 – S_{100}	1.27 b	0.96 b	1.11 b
S_3 – S_{125}	1.35 a	0.99 a	1.17 a
S.Em. ±	0.01	0.01	0.01
Nitrogen levels (N) kg ha^{-1}			
N_1 - 90	1.13 c	0.89 c	1.01 c
N_2 - 120	1.25 b	0.94 b	1.10 b
N_3 - 150	1.50 a	1.07 a	1.29 a
S.Em. ±	0.01	0.01	0.01
Interaction (G × S × N)			
G_1 S_1 N_1	1.04 k	0.88 e	0.96 g
G_1 S_1 N_2	1.19 hi	0.91 de	1.05 de
G_1 S_1N_3	1.39 d-f	1.06 bc	1.23 b
G_1 S_2 N_1	1.08 jk	0.90 de	0.99 fg
G_1 S_2 N_2	1.14 ij	0.94 de	1.04 e
G_1 S_2 N_3	1.41 de	1.06 bc	1.23 b
G_1 S_3 N_1	1.13 i-k	0.90 de	1.02 e-g
G_1 S_3 N_2	1.25 gh	0.95 d	1.10 cd
G_1 S_3 N_3	1.59 ab	1.10 ab	1.34 a
G_2 S_1 N_1	1.18 h-j	0.90 de	1.04 e
G_2 S_1 N_2	1.30 fg	0.94 de	1.12 c
G_2 S_1 N_3	1.46 cd	1.04 c	1.25 b
G_2 S_2 N_1	1.19 hi	0.88 e	1.03 ef
G_2 S_2 N_2	1.32 e-g	0.94 de	1.13 c
G_2 S_2 N_3	1.52 bc	1.04 c	1.28 b
G_2 S_3 N_1	1.17 h-j	0.91 de	1.04 e
G_2 S_3 N_2	1.30 fg	0.95 d	1.13 c
G_2 S_3 N_3	1.63 a	1.14 a	1.39 a
S.Em. ±	0.03	0.02	0.02

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT ($P = 0.05$)

Table 22: Nitrogen uptake (kg ha^{-1}) of oat genotypes as influenced by seed rate and nitrogen levels

Treatment	First harvest	Second harvest	Total
Genotypes (G)			
G_1 – OS-6	78.0 b	38.7 b	116.6 b
G_2 - JHO-822	87.6 a	42.8 a	130.4 a
S.Em. ±	1.05	0.80	1.34
Seed rate (S) kg ha^{-1}			
S_1 – S_{75}	73.5 c	36.6 b	110.1 c
S_2 – S_{100}	78.7 b	38.8 b	117.5 b
S_3 – S_{125}	96.1 a	46.9 a	143.0 a
S.Em. ±	1.29	0.98	1.65
Nitrogen levels (N) kg ha^{-1}			
N_1 - 90	62.2 c	32.3 c	94.5 c
N_2 - 120	75.9 b	37.8 b	113.7 b
N_3 - 150	110.2 a	52.2 a	162.4 a
S.Em. ±	1.29	0.98	1.65
Interaction (G × S × N)			
$G_1 S_1 N_1$	56.0 hi	27.2 h	83.2 h
$G_1 S_1 N_2$	67.6 fg	32.9 e-h	100.5 fg
$G_1 S_1 N_3$	91.0 d	45.2 b-d	136.2 d
$G_1 S_2 N_1$	54.8 i	29.4 gh	84.2 h
$G_1 S_2 N_2$	67.7 fg	34.8 e-h	102.4 fg
$G_1 S_2 N_3$	93.4 d	45.6 b-d	139.0 d
$G_1 S_3 N_1$	63.7 f-i	33.7 e-h	97.4 fg
$G_1 S_3 N_2$	78.1 e	38.7 d-f	116.8 e
$G_1 S_3 N_3$	129.5 b	60.5 a	190.0 b
$G_2 S_1 N_1$	61.1 g-i	31.2 f-h	92.3 gh
$G_2 S_1 N_2$	72.9 ef	36.4 e-g	109.3 ef
$G_2 S_1 N_3$	92.5 d	46.8 bc	139.3 d
$G_2 S_2 N_1$	65.3 f-h	34.5 e-h	99.8 fg
$G_2 S_2 N_2$	80.1 e	39.3 c-e	119.4 e
$G_2 S_2 N_3$	110.8 c	49.1 b	159.9 c
$G_2 S_3 N_1$	72.1 ef	37.8 d-f	109.9 ef
$G_2 S_3 N_2$	89.4 d	44.6 b-d	133.9 d
$G_2 S_3 N_3$	143.8 a	66.1 a	209.9 a
S.Em. ±	3.15	2.41	4.03

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

During first, second harvests and total, significant and linear increase in nitrogen uptake was noticed with increase in seed rate. Significantly higher nitrogen uptake was recorded with seed rate of 125 kg per ha during first harvest (96.1 kg ha^{-1}), second harvest (46.9 kg ha^{-1}) and total (143.0 kg ha^{-1}). However, lower seed rate of 75 kg per ha recorded significantly lower nitrogen uptake (73.5, 36.6 and 110.1 kg ha^{-1} during first, second harvests and total respectively). It was on par with 100 kg par ha seed rate during second harvest.

There was linear and significant increase in nitrogen uptake with increase in nitrogen level. Higher nitrogen level of 150 kg per ha recorded significantly higher nitrogen uptake during first harvest (110.2 kg ha^{-1}), second harvest (52.2 kg ha^{-1}) and total (162.4 kg ha^{-1}). Significantly least nitrogen uptake was recorded with lower nitrogen level of 90 kg per ha (62.2, 32.3 and 94.5 kg ha^{-1}, respectively).

Interaction effect was significant during first, second harvests and total. The treatment combination $G_2S_3N_3$ *i.e.*, genotype JHO-822 with 125 kg per ha seed rate at 150 kg per ha nitrogen recorded significantly higher nitrogen uptake (143.8, 66.1 and 209.9 kg ha^{-1}, respectively). It was on par with $G_1S_3N_3$ *i.e.*, genotype OS-6 with 125 kg per ha seed rate at 150 kg per ha nitrogen (60.50 kg ha^{-1}) during second harvest.

Significantly least plant nitrogen content was recorded with $G_1S_1N_1$ *i.e.*, genotype OS-6 with 75 kg per ha seed rate at 90 kg per ha nitrogen (54.8, 27.2 and 82.0 kg ha^{-1}, respectively).

4.4.3 Available nitrogen status in soil after the second harvest (cf. Table 23)

The oat genotypes and seed rates did not differ significantly with respect to available soil nitrogen.

There was linear and significant increase in available soil nitrogen with increase in nitrogen level. Higher nitrogen level of 150 kg per ha recorded significantly higher available nitrogen (214.80 kg ha^{-1}). Significantly least available nitrogen was recorded with lower nitrogen level of 90 kg per ha (205.37 kg ha^{-1}).

Interaction effect was significant. There was linear and significant increase in soil available nitrogen with increase in nitrogen level irrespective of genotypes and seed rate. The treatment combination $G_2S_3N_3$ *i.e.*, genotype JHO-822 with 125 kg per ha seed rate at 150 kg per ha nitrogen recorded significantly higher available nitrogen in soil (215.22 kg ha^{-1}). It was significant over rest of the combinations except $G_1S_3N_3$, $G_2S_2N_3$, $G_2S_1N_3$, $G_1S_2N_3$ and $G_1S_1N_3$. Significantly least available nitrogen in soil was recorded with $G_1S_1N_1$ *i.e.*, genotype OS-6 with 75 kg per ha seed rate at 90 kg per ha nitrogen (204.82 kg ha^{-1}).

4.5 Economics

4.5.1 Gross returns (cf. Table 24)

The oat genotypes differed significantly with respect to gross returns. The genotype JHO-822 recorded significantly higher gross returns (Rs. 34,324 ha^{-1}) over OS-6 (Rs. 33,177 ha^{-1}).

There was linear and significant increase in gross returns with increase in seed rate. Significantly higher gross returns was recorded with seed rate of 125 kg per ha (Rs. 37,373 ha^{-1}) and lower seed rate of 75 kg per ha recorded significantly lower gross returns (Rs. 30,877 ha^{-1}).

There was linear and significant increase in gross returns with increase in nitrogen level. Higher nitrogen level of 150 kg per ha recorded significantly higher gross returns (Rs. 37,545 ha^{-1}). Significantly least gross returns was recorded with lower nitrogen level of 90 kg per ha (Rs. 30,761 ha^{-1})

Interaction effect was significant. The treatment combination $G_2S_3N_3$ *i.e.*, genotype JHO-822 with 125 kg per ha seed rate at 150 kg per ha nitrogen recorded significantly higher gross returns (Rs. 44,300 ha^{-1}) over rest of the combinations. Next best combination was $G_1S_3N_3$ *i.e.*, OS-6 with 125 kg per ha seed rate at 150 kg per ha nitrogen (Rs. 42,292 ha^{-1}). Significantly least gross returns was recorded with $G_1S_1N_1$ *i.e.*, genotype OS-6 with 75 kg per ha seed rate at 90 kg per ha nitrogen (Rs. 28,660 ha^{-1}).

Table 23: Available nitrogen status in soil after the second harvest of oat genotypes as influenced by seed rate and nitrogen level

Treatment	Available nitrogen (kg ha^{-1})
Genotype (G)	
G_1 – OS-6	209.38 a
G_2 - JHO-822	209.76 a
S.Em. ±	0.15
Seed rate (S) kg ha^{-1}	
S_1 – S_{75}	209.42 a
S_2 – S_{100}	209.77 a
S_3 – S_{125}	209.52 a
S.Em. ±	0.18
Nitrogen level (N) kg ha^{-1}	
N_1 - 90	205.37 c
N_2 - 120	208.53 b
N_3 - 150	214.80 a
S.Em. ±	0.18
Interaction (G × S × N)	
G_1 S_1 N_1	204.82 d
G_1 S_1 N_2	208.22 bc
G_1 S_1N_3	214.72 a
G_1 S_2 N_1	206.85 c
G_1 S_2 N_2	208.12 bc
G_1 S_2 N_3	214.22 a
G_1 S_3 N_1	205.12 d
G_1 S_3 N_2	208.12 bc
G_1 S_3 N_3	214.22 a
G_2 S_1 N_1	205.22 d
G_2 S_1 N_2	208.32 b
G_2 S_1 N_3	215.22 a
G_2 S_2 N_1	205.02 d
G_2 S_2 N_2	209.22 b
G_2 S_2 N_3	215.22 a
G_2 S_3 N_1	205.22 d
G_2 S_3 N_2	209.22 b
G_2 S_3 N_3	215.22 a
S.Em. ±	0.45

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT ($P = 0.05$)

Table 24: Economics of cultivation of oat genotypes as influenced by seed rate and nitrogen levels

Treatment	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	Benefit cost ratio
Genotypes (G)			
G_1 – OS-6	33177 b	18441 b	2.25 b
G_2 - JHO-822	34324 a	19587 a	2.32 a
S.Em. ±	211	211	0.01
Seed rate (S) kg ha^{-1}			
S_1 – S_{75}	30877 c	16140 c	2.09 c
S_2 – S_{100}	33002 b	18265 b	2.24 b
S_3 – S_{125}	37373 a	22636 a	2.53 a
S.Em. ±	259	259	0.02
Nitrogen levels (N) kg ha^{-1}			
N_1 - 90	30761 c	16813 c	2.21 b
N_2 - 120	32946 b	18209 b	2.24 b
N_3 - 150	37545 a	22020 a	2.42 a
S.Em. ±	259	259	0.02
Interaction (G × S × N)			
G_1 S_1 N_1	28660 k	14713 k	2.05 h
G_1 S_1 N_2	30252 i-k	15515 i-k	2.05 h
G_1 S_1N_3	33440 d-f	17914 e-h	2.15 gh
G_1 S_2 N_1	29780 jk	15833 i-k	2.14 gh
G_1 S_2 N_2	32140 f-i	17403 f-i	2.18 gh
G_1 S_2 N_3	34620 de	19094 d-f	2.23 e-g
G_1 S_3 N_1	32660 e-h	18713 d-g	2.34 d-f
G_1 S_3 N_2	34752 d	20015 d	2.36 c-e
G_1 S_3 N_3	42292 b	26766 b	2.72 b
G_2 S_1 N_1	29218 jk	15271 jk	2.09 gh
G_2 S_1 N_2	30932 g-j	16195 h-k	2.10 gh
G_2 S_1 N_3	32760 d-h	17234 f-j	2.11 gh
G_2 S_2 N_1	30760 h-j	16813 g-j	2.21 fg
G_2 S_2 N_2	32852 d-g	18115 d-h	2.23 e-g
G_2 S_2 N_3	37860 c	22334 c	2.44 cd
G_2 S_3 N_1	33486 d-f	19539 de	2.40 cd
G_2 S_3 N_2	36746 c	22009 c	2.49 c
G_2 S_3 N_3	44300 a	28774 a	2.85 a
S.Em. ±	633	633	0.04

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

4.5.2 Net returns (cf. Table 24)

The oat genotypes differed significantly with respect to net returns. The genotype JHO-822 recorded significantly higher net return (Rs. 19,587 ha^{-1}) over OS-6 (Rs. 18,441 ha^{-1}).

The net returns increased linearly and significantly with increase in seed rate. Significantly higher net returns was recorded with seed rate of 125 kg per ha (Rs. 22,636 ha^{-1}). However, lower seed rate of 75 kg per ha recorded significantly lower net returns (Rs. 16,140 ha^{-1}).

There was linear and significant increase in net returns with increase in nitrogen level. Higher nitrogen level of 150 kg per ha recorded significantly higher net returns (Rs. 22,020 ha^{-1}) and significantly least net returns was recorded with lower nitrogen level of 90 kg per ha (Rs. 16,813 ha^{-1}).

Interaction effect was significant. The treatment combination $G_2S_3N_3$ *i.e.*, genotype JHO-822 with 125 kg per ha seed rate at 150 kg per ha nitrogen recorded significantly higher net returns (Rs. 28,774 ha^{-1}) over rest of the combinations. Next best combination was $G_1S_3N_3$ *i.e.*, OS-6 with 125 kg per ha seed rate at 150 kg per ha nitrogen (Rs. 26,766 ha^{-1}). Significantly least net return was recorded with $G_1S_1N_1$ *i.e.*, genotype OS-6 with 75 kg per ha seed rate at 90 kg per ha nitrogen (Rs. 14,713 ha^{-1}).

4.5.3 Benefit cost ratio (cf. Table 24)

The oat genotypes differed significantly. The genotype JHO-822 recorded significantly higher benefit cost ratio (2.32) over OS-6 (2.25).

There was linear and significant increase in benefit cost ratio with increase in seed rate. Significantly higher benefit cost ratio was recorded with seed rate of 125 kg per ha (2.53). Lower seed rate of 75 kg per ha recorded significantly lower benefit cost ratio (2.09).

Higher nitrogen level of 150 kg per ha recorded significantly higher benefit cost ratio (2.42). Significantly least benefit cost ratio was recorded with lower nitrogen level of 90 kg per ha (2.21).

Interaction effect due to genotype, seed rate and nitrogen levels was significant. The treatment combination $G_2S_3N_3$ *i.e.*, genotype JHO-822 with 125 kg per ha seed rate at 150 kg per ha nitrogen recorded significantly higher benefit cost ratio (2.85) over rest of the combinations. Next best combination was $G_1S_3N_3$ *i.e.*, OS-6 with 125 kg per ha seed rate at 150 kg per ha nitrogen (2.72). Significantly least benefit cost ratio was recorded with $G_1S_1N_1$ *i.e.*, genotype OS-6 with 75 kg per ha seed rate at 90 kg per ha nitrogen (2.05).

5. DISCUSSION

The results of the field experiment conducted at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka, during *rabi* 2010-11 to study the response of oat genotypes to seed rate and nitrogen levels on forage yield and quality under irrigation are discussed in this chapter.

5.1 Weather conditions and crop performance

Crop growth is mainly dependent on environmental factors and fluctuation in weather conditions. The meteorological data revealed that during the experimental year 2010-11, the rainfall received was 1007.7 mm (Table 2) which was 232.4 mm higher than the average rainfall of past 60 years (1950-2009). The rainfall during the cropping period was 42 mm (November to March) and crop growth was normal. The oat crop was sown on 21-11-2010 with sufficient stored soil moisture conditions.

The crop was irrigated at an interval of 12 – 15 days so as to maintain adequate soil moisture. The crop was free from any biotic and abiotic stresses.

The mean maximum temperature recorded during the experimentation was in the range of 28.9℃ (November) to 35.2℃ (March), while minimum temperature ranged from 12.5℃ (January) to 14 ℃ (February). Both maximum and minimum temperatures were favourable for normal growth and development of oat and the temperature did not deviate much from the average of past 60 years.

5.2 Effect of genotypes

5.2.1 Growth and forage yield

The oat genotype JHO-822 produced significantly higher total green forage yield (57.21 t ha^{-1}) and total dry matter yield (10.87 t ha^{-1}) compared to the genotype OS-6 (55.30 t ha^{-1} and 10.51 t ha^{-1}, respectively) (Table 12 and 13). Similar trend followed during first harvest for green forage yield and dry matter yield. However, during second harvest, the effect was non significant. The genotype JHO-822 produced 3.45 per cent higher total green forage yield and 3.42 per cent higher total dry matter yield compared to OS-6.

This forage yield increase in JHO-822 oat genotype was mainly due to significantly higher number of shoots per m row length (Table 5) during first and second harvests (219.04 and 134.70, respectively) though rest of the growth and yield parameters showed harvest wise non significant difference. These findings are in conformity with the findings of Rao *et al.* (1978), Taneja *et al.* (1981), Joshi and Singh (1982), Joshi *et al.* (1996), Bali *et al.* (1998), Singh *et al.*(1998) and Habib *et al.* (2003).

5.2.2 Forage quality

Though there was non-significant difference between oat genotype for the contents of important quality parameters viz., crude protein, ether extract, crude fibre and nitrogen free extract, the genotype JHO-822 recorded significantly higher content of total ash (Table 18), while the genotype OS-6 recorded higher content of organic matter (Table 14) and total carbohydrate (Table 20). The oat genotypes also did not differ significantly for the content of important quality parameters as per the findings of Kakol *et al.* (2003).

Irrespective of first or second harvest and for total of two harvests, the genotype JHO-822 recorded significantly higher yields of quality parameters viz., organic matter (9858 kg ha^{-1}, Table 14), crude protein (769 kg ha^{-1}, Table 15), ether extract (255 kg ha^{-1}, Table 16), crude fibre (2644 kg ha^{-1}, Table 17), total ash (1037 kg ha^{-1}, Table 18), nitrogen free extract (6137 kg ha^{-1}, Table 19) and total carbohydrates (8780 kg ha^{-1}, Table 20). Higher yields of these quality parameters in genotype JHO-822 was mainly due to its significantly higher (6.56%, 6.50%, 8.51%, 8.05%, 9.50%, 5.22% and 6.05%, respectively) dry matter yield compared to OS-6.

5.2.3 Palatability

Both the oat genotypes showed 100 per cent palatability during both the harvests. This was mainly due to thin and succulent stem.

5.3 Effect of seed rate

5.3.1 Growth and forage yield

There was linear and significant increase in green forage yield and dry matter yield during first, second harvest and for total of two harvests with increase in seed rate. The seed rate of 125 kg ha^{-1} produced significantly higher green forage yield (37.20 t ha^{-1} during first harvest, 25.09 t ha^{-1} during second harvest and 62.29 t ha^{-1} total) compared to 75 and 100 kg ha^{-1} seed rate. This yield increase was 13.48, 12.91 and 13.25 per cent higher during first, second harvests and for total, respectively compared to 100 kg ha^{-1} seed rate and 20.50, 21.85 and 21.04 per cent higher, respectively compared to 75 kg ha^{-1} seed rate.

The dry matter yield followed the similar trend recording significantly higher yield of 7.07 t ha^{-1} during first harvest, 4.77 t ha^{-1} during second harvest and 11.83 t ha^{-1} for total of two harvests with 125 kg ha^{-1} seed rate.

This yield increase was mainly due to significantly higher plant height (91.61 cm and 56.08 cm during first, second harvests, Table 4), number of shoots per meter row length (224.50 and 140.11 during first and second harvests, Table 5), fresh weight per meter row length (1237.33 and 398.56 during first and second harvests, Table 7) and number of seedlings per meter row length (44.33 and 39.33 during first and second harvests, Table 6) recorded with 125 kg ha^{-1} seed rates. Though, the per plant performance due to different seed rates was almost non-significant. The number of plants per unit area played an important role in increasing the biomass production due to increase in photosynthetic area.

These results are in agreement with the findings of Singh *et al.* (1979), Uhliar (1979), Veera Raghavaiah *et al.* (1979), Sing *et al.* (1989), Droushiotis (1990), Han and Kim (1992), Jan and Jan (1994) and Kakol *et al.* (2003).

5.3.2 Forage quality

There was linear increase in the content of quality parameters with increase in seed rate for crude protein (7.82 and 6.19 % during first and second harvests), ether extract (2.25 and 2.49 % during first and second harvests) and total ash (9.73 and 9.90% during first and second harvests). While, there was negative relation with increase in seed rate for the contents of organic matter (90.27 and 90.10 % during first and second harvests), crude fibre (20.00 and 29.43 % during first and second harvests), nitrogen free extract (50.60 and 51.99 % during first and second harvests), and total carbohydrates (79.60 and 81.42 % during first and second harvests).

The higher crude protein content and lower crude fibre content with increase in seed rate was due to thinner plants in higher seed rate *i.e.*, higher plant population These results are in agreement with the findings of Uhliar (1979), Veera Raghavaiah *et al.* (1979), Lowe *et al.* (1980), Droushiotis (1990) and Kakol *et al.* (2003).

The total yield of quality parameters of two harvests increased linearly and significantly with increase in seed rate. The seed rate of 125 kg ha^{-1} recorded significantly higher total yield of all the quality parameters with yield of crude protein (843 kg ha^{-1}), ether extract (277 kg ha^{-1}), total ash (1169 kg ha^{-1}), and nitrogen free extract (6623 kg ha^{-1}). Similar trend followed during first and second harvests. The higher yields of quality parameters with higher seed rate was due to significantly higher (16.92, 16.38, 23.57 and 13.99 per cent increase, respectively) compared to 100 kg ha^{-1} seed rate and 25.44, 26.48, 35.77 and 19.96 per cent increase, respectively compared to 75 kg ha^{-1} seed rate in dry matter yield. These results are in conformity with Kakol (2000).

5.3.3 Palatability

Irrespective of seed rate, the palatability of oat fodder was 100 per cent during both the harvests. This was mainly due to thin and succulent stem.

5.4 Effect of nitrogen levels

5.4.1 Growth and forage yield

There was linear and significant increase in green forage yield and dry matter yield during first, second harvests and total of two harvests with successive increase in nitrogen levels upto 150 kg ha^{-1}. The nitrogen level of 150 kg ha^{-1} produced significantly higher green forage yield (38.44 t ha^{-1} during first harvest, 24.14 t ha^{-1} during second harvest and 62.58 t ha^{-1} for total) compared to 90 and 120 kg ha^{-1} nitrogen. This yield increase was 18.05, 8.00 and 13.96 per cent higher during first harvest, second harvest and for total, respectively compared to 120 kg ha^{-1} nitrogen and 28.73, 12.75 and 22.05 per cent, higher, respectively compared to 90 kg ha^{-1} nitrogen.

The dry matter yield followed the similar trend recording significantly higher yield of 7.30 t ha^{-1} during first harvests, 4.59 t ha^{-1} during second harvests and 11.89 t ha^{-1} for total of two harvests with 150 kg ha^{-1} nitrogen.

This yield increase was mainly due to significantly higher performance of all the growth parameters viz., plant height (92.13 and 51.87 cm during first and second harvests), number of shoots per meter row length (230.44 and 137.61 cm during first and second harvests), number of seedlings per meter row length (39.22 and 34.22 cm during first and second harvests), fresh weight per meter row length (1150.89 and 378.89 cm during first and second harvests), and leaf to stem ratio (2.43 and 0.514 during first and second harvests) recorded with 150 kg ha^{-1} nitrogen. Singh *et al.* (1989) opined that the beneficial effects of nitrogen on cell division and elongation, formation of nucleotides and co-enzymes resulted in increased meristematic activity and photosynthetic area and hence more production and accumulation of photosynthates which reflects the higher yield. The results of increased green forage and dry matter yields due to improvement in growth and yield parameters are in conformity with the findings of various workers *viz*., Agrawal *et al.* (1993), Dubey *et al.* (1995), Pradhan and Mohapatra (1995) and Singh *et al.* (1997) wherein linear response to nitrogen was also observed.

The significantly higher performance of all the growth and yield parameters recorded during all the growth stages with higher level of nitrogen is in conformity with the findings of Bali *et al.* (1998), Havlin *et al.* (1999), Chakraborty *et al.* (1999), Singh *et al.* (1999), Midha *et al.* (1999), Sharma *et al.* (2001), Thakuria add Gogoi (2001), Sharma and Bhunia (2001), Hasan *et al.* (2000), Suhrawardy and Kalita (2001), Singh *et al.* (2000) and Barik and Roy (2002).

5.4.2 Forage quality

There was linear increase in the contents of quality parameters with increase in nitrogen level for crude protein (7.98 and 6.70% during first and second harvests), ether extract (2.42 and 2.57% during first and second harvests) and total ash (10.06 and 10.33% during first and second harvests) at 150 kg ha^{-1} nitrogen. While, there was negative relation with increase in nitrogen level for the contents of organic matter (89.94 and 89.67% during first and second harvests), crude fibre (18.97 and 28.49% during first and second harvests) and total carbohydrates (78.15 and 80.40% during first and second harvests).

The higher crude protein content and lower crude fibre content with increase in nitrogen level was due to the fact that application of nitrogen generally resulted in availability of adequate nutrients thereby more uptake and correspondingly increase in the protein content of herbage. The results are in conformity with the findings of Shrivastava *et al.* (1973), Joshi and Rajendraprasad (1979), Tomer (1970), Tiwana *et al.* (1976), Chaturvedi (1981), Das *et al.* (1974), Sharma *et al.* (2001), Givens *et al.* (2004), Kumar (1998), Kakol *et al.* (2003), Singh *et al.* (1997), Sheoran *et al.* (1998), Bali *et al.* (1998), Reddy and Tomer (1988), Naveen and Sood (1995) and Mandal *et al.* (2000).

Total ash and ether extract contents increased significantly with increased nitrogen levels. Whereas, organic matter and total carbohydrates contents decreased significantly with increased nitrogen levels. It has been documented that application of nitrogen, causes increased meristematic activity and in this condition more mineral salts are absorbed and the respiration process becomes rapid which leads to conversion of most of the carbohydrates into fats (Meyer and Anderson, 1952).

With the application of nitrogen not only protein content is improved but mineral salts (total ash) and crude fats (ether extract) are also improved and this has been the cause for reduced proportion of carbohydrates (Tomer, 1970). The similar results have been reported by Tiwana *et al.* (1976) and Joshi and Rajendraprasad (1979).

The total yield of all the quality parameters of two harvests increased linearly and significantly with increase in nitrogen level. The nitrogen level of 150 kg ha^{-1} recorded significantly higher total yield of the quality parameters viz., organic matter (10907 kg ha^{-1}), crude protein (906 kg ha^{-1}), ether extract (302 kg ha^{-1}), crude fibre (2759 kg ha^{-1}), total ash (1248 kg ha^{-1}), nitrogen free extract (6830 kg ha^{-1}) and total carbohydrates (9589 kg ha^{-1}). Similar trend was also followed during first and second harvests. The higher yields of quality parameters with higher nitrogen level was due to significantly higher (20.07 and 13.99%) increase over 90 and 120 kg ha^{-1} nitrogen in total dry matter yield. These results are in conformity with the findings of Thakuria (1992), Pradhan and Mishra (1994), Sheoran *et al.* (1998), Bali *et al.* (1998), Patel and Rajagopal (2002) and Kakol *et al.* (2003).

5.4.3 Palatability

Irrespective of nitrogen level, the palatability of oat fodder was 100 per cent during both the harvests. This was mainly due to thin and succulent stem.

5.5 Interaction effect

5.5.1 Growth and forage yield

There was significant interaction amongst genotypes, seed rate and nitrogen level on growth, yield and quality of forage oat.

Significantly higher interaction for green forage yield (46.07, 27.77 and 73.83 t ha^{-1} during first harvest, second harvest and total of two harvests, respectively) and dry matter yield (8.75, 5.28 and 14.03 t ha^{-1} during first harvest, second harvest and total of two harvests, respectively) were recorded with interaction $G_2S_3N_3$ *i.e.*, JHO-822 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen (Fig. 3 and Plate 3). This was mainly due to significantly higher performance of growth and yield parameters during first and second harvests viz., plant height (100.67 and 60.37 cm, respectively), number of shoots per meter row length (238.00 and 148.00), number of seedlings per meter row length (45.33 and 40.33), fresh weight per meter row length (1250.00 and 411.00 g) and leaf to stem ratio (2.47 and 0.533).

This indicated that the plant growth and biomass production was optimum in $G_2S_3N_3$ *i.e.*, JHO-822 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen leading to significantly higher yields.

The results of individual effect also indicated the significantly higher effect of oat genotype JHO-822 (G-2), seed rate of 125 kg ha^{-1} (S_3) and 150 kg ha^{-1} nitrogen (N_3). These results are also in agreement with Uhliar (1979), Veera Raghavaiah *et al.,* (1979), Ulmann (1989), Han and Kim (1992), who also obtained higher interaction for green forage yield with higher levels of seed rate and nitrogen.

The next best significantly higher interaction for green forage yield (43.13, 27.35 and 70.49 t ha^{-1} during first harvest, second harvest and total of two harvests, respectively) and dry matter yield (8.20, 5.20 and 13.39 t ha^{-1} during first harvest, second harvest and total of two harvests, respectively) was recorded with interaction $G_1S_3N_3$ *i.e.*, OS-6 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen (Fig. 3 and Plate 3). This was mainly due to higher performance of growth and yield parameters during first and second harvests in this interaction viz., number of shoots per meter row length (235.00 and 142.33, respectively), number of seedlings per meter row length (45.00 and 40.00, respectively), fresh weight per meter row length (1245.33 and 409.67, respectively), and leaf to stem ratio (2.40 and 0.527, respectively).

Irrespective of seed rate and nitrogen level, the interaction effect with $G_1S_1N_1$ *i.e.*, OS-6 with 75 kg ha^{-1} seed rate at 90 kg ha^{-1} nitrogen recorded significantly lower green forage yield (27.90, 19.87 and 47.77 t ha^{-1} during first harvest, second harvest and total of two harvests, respectively) and dry matter yield (5.30, 3.77 and 9.08 t ha^{-1} during first harvest, second harvest and total of two harvests, respectively).

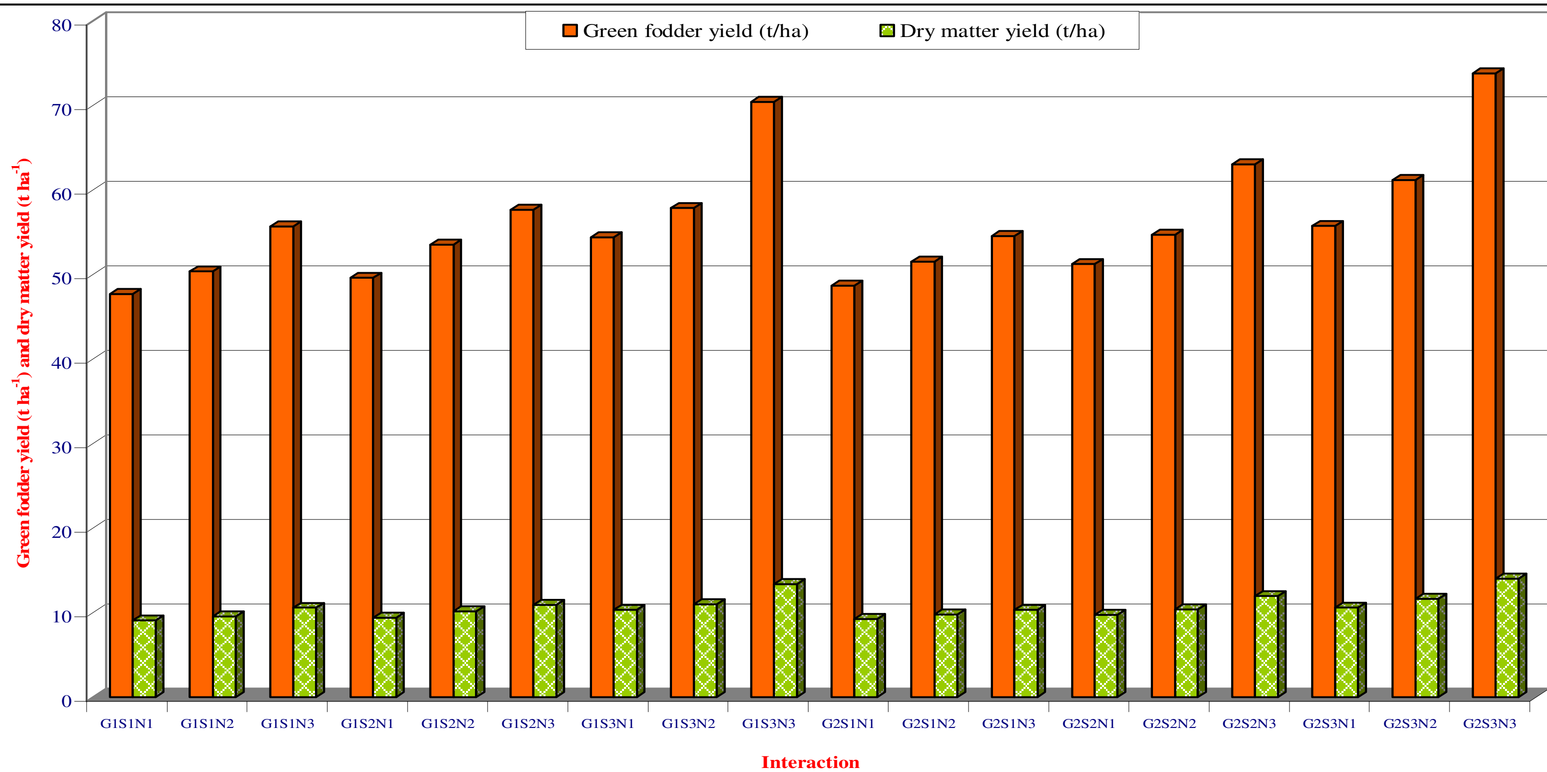

Fig. 3: Green fodder and dry matter yield of oat genotypes as influenced by seed rate and nitrogen levels

Fig. 3: Green fodder and dry matter yield of oat genotypes as influenced by seed rate and nitrogen levels

Genotypes JHO-822 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen ($G_2S_3N_3$)

Genotypes OS-6 with 125 kg ha-1 seed rate at 150 kg ha-1 nitrogen (G1S3N3)

Plate 3. High yielding interactions

This was due to significantly lower performance of growth and yield parameters in this interaction and the significantly least individual effect of oat genotype OS-6, 75 kg ha^{-1} seed rate and 90 kg ha^{-1} nitrogen for green forage yield and dry matter yield.

5.5.2 Forage quality

The significantly higher forage yielding interaction $G_2S_3N_3$ *i.e.*, JHO-822 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen recorded significantly higher contents of quality parameters during first and second harvests viz., crude protein (8.28 and 7.12, respectively), ether extract (2.51 and 2.66, respectively) and total ash (11.55 and 11.83, respectively) and significantly lower organic matter (88.45 and 88.17, respectively), crude fibre (17.64 and 28.41, respectively), and total carbohydrates (75.74 and 78.39, respectively). This was mainly due to significant individual effect of higher seed rate and higher nitrogen level.

The interaction effect of total yield of all the quality parameters was significantly higher in $G_2S_3N_3$ *i.e.*, JHO-822 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen. It recorded significantly higher yields of organic matter (12851 kg ha^{-1}), crude protein (1104 kg ha^{-1}), ether extract (373 kg ha^{-1}), total ash (1697 kg ha^{-1}), nitrogen free extract (7982 kg ha^{-1}) and total carbohydrates (11170 kg ha^{-1}). Similar trend followed during first and second harvests.

This was mainly due to the significantly higher interaction and the individual effects of higher seed rate and nitrogen recorded for dry matter yield.

The interaction $G_1S_3N_3$ *i.e.*, OS-6 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen was on par with $G_2S_3N_3$ *i.e.*, JHO-822 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen for the yield of all the quality parameters.

5.5.3 Palatability

Irrespective of oat genotypes, seed rate and nitrogen level, the difference in interaction effect for palatability of oat fodder was not observed during both the harvests. This was mainly due to thin and succulent stem.

5.6 Economics

5.6.1 Effect of genotypes

The oat genotype JHO-822 recorded significantly higher gross returns (Rs. 34,324 ha^{-1}), net returns (Rs. 19,587 ha^{-1}) and benefit cost ratio (2.32) compared to OS-6. This was mainly due to significantly higher green forage production in JHO-822.

5.6.2 Effect of seed rate

There was linear and significant increase with increase in seed rate with respect to gross returns, net returns and benefit cost ratio. Higher seed rate of 125 kg ha^{-1} recorded significantly higher gross returns (Rs. 37,373 ha^{-1}), net returns (22,636 ha^{-1}) and benefit cost ratio (2.53). This was mainly due to significantly higher green forage production with higher seed rate.

5.6.3 Effect of nitrogen level

There was linear increase with increase in nitrogen level with respect to gross returns, net returns and benefit cost ratio. Higher nitrogen level of 150 kg ha^{-1} nitrogen recorded significantly higher gross returns (Rs. 37,545 ha^{-1}), net returns (Rs. 22,020 ha^{-1}) and benefit cost ratio (2.42). This was mainly due to significantly higher green forage production with higher nitrogen level.

5.6.4 Interaction effect

Significantly higher interaction effect was recorded in $G_2S_3N_3$ *i.e.*, JHO-822 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen compared to rest of the interactions for gross returns (Rs. 44,300 ha^{-1}), net returns (Rs. 28,774 ha^{-1}) and benefit cost ratio (2.85, Fig. 8). This was mainly due to significantly higher green forage yield recorded with this interaction. These results are in conformity with the findings of Veera Ragavaiah *et al.* (1979), Taneja *et al.* (1981), Reddy and Tomer (1985), Reddy and Hussain (1990), Patel and Patel (1991), Pradhan and Misra (1994) and Singh *et al.* (1998).

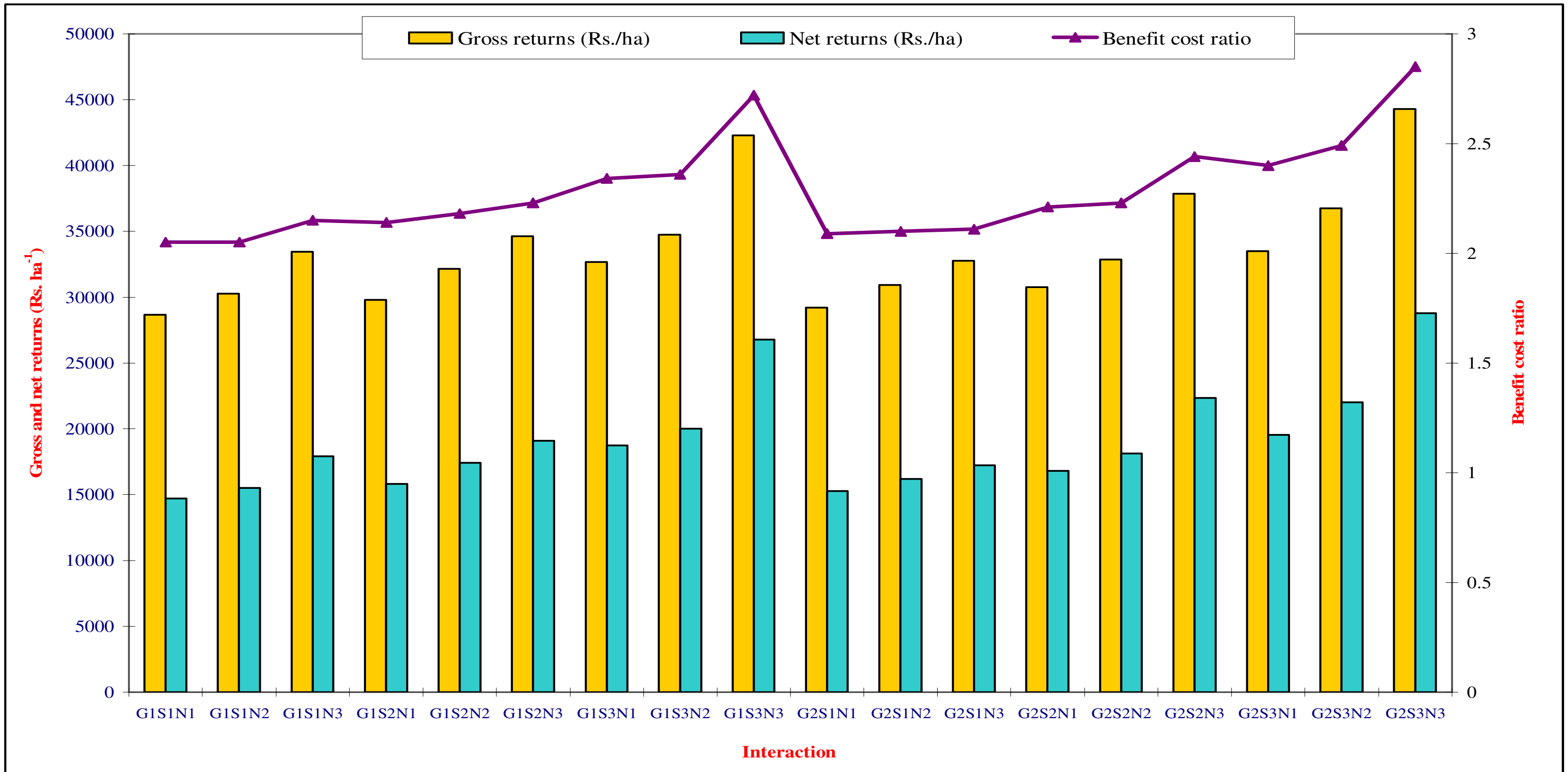

Fig. 8: Economics of oat genotypes as influenced by seed rate and nitrogen levels

Fig. 8: Economics of oat genotypes as influenced by seed rate and nitrogen levels

The next best interaction for economic advantage was $G_1S_3N_3$ *i.e.*, OS-6 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen and significantly least interaction was recorded in $G_1S_1N_1$ *i.e.*, OS-6 with 75 kg ha^{-1} seed rate at 90 kg ha^{-1} nitrogen.

5.7 Plant nitrogen, uptake and available soil nitrogen

There was linear increase in plant nitrogen content with increase in nitrogen level irrespective of genotype and seed rate. The interaction $G_2S_3N_3$ *i.e.*, JHO-822 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen recorded significantly higher plant nitrogen content (1.63, 1.14 and 1.69% during first harvest, second harvest and for total, respectively). It was on par with $G_1S_3N_3$ *i.e.*, OS-6 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen.

The interaction $G_2S_3N_3$ *i.e.*, JHO-822 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen recorded significantly higher nitrogen uptake (143.8, 66.1 and 209.9 kg ha^{-1} during first harvest, second harvest and total, respectively). It was on par with interaction $G_1S_3N_3$ *i.e.*, OS-6 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen.

There was linear and significant increase in soil available nitrogen with increase in nitrogen level, irrespective of genotype and seed rate. The interaction $G_2S_3N_3$ *i.e.*, JHO-822 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen recorded significantly higher available nitrogen in soil (215.22 kg ha^{-1}). It was on par with interaction $G_1S_3N_3$ *i.e.*, OS-6 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen. These results are in conformity with the findings of Verma (1984), Hazra and Tripathi (1986), Trofymow *et al.* (1987), Peterson (1988), Bhagwati *et al.* (1989), Collins *et al.* (1990), Tripathi (1994), Kirikham and Wilkins (1994), Hopkins *et al.* (1994), Chakraborty *et al.* (1999) and Pederson *et al.* (2002).

Results of practical utility

Oat genotype JHO-822 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen produced significantly higher total green forage (73.83 t ha^{-1}), net returns (Rs. 28,774 ha^{-1}) and benefit cost ratio (2.85) with superior forage quality in northern transition zone under irrigation.

Future line of work

1. Evaluation of potential multicut oat genotypes under irrigation.
2. There is scope for studies with further increase in the nitrogen levels along with levels of phosphorus and potassium.

6. SUMMARY AND CONCLUSIONS

A field experiment was conducted at the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad in Northern Transition Zone of Karnataka on black clay soil to study the response of oat genotypes to seed rate and nitrogen levels on forage yield and quality under irrigation during *rabi* 2010-11. The experiment was laid out in randomized complete block design with 18 treatment combinations involving two genotypes (JHO-822 and OS-6), three seed rates (75, 100 and 125 kg ha^{-1}) and three levels of nitrogen (90,120 and 150 kg ha^{-1}). The salient findings of the experiment are summarized in this chapter.

Effect of genotypes

The oat genotype JHO-822 produced significantly higher total green forage yield (57.21 t ha^{-1}) and total dry matter yield (10.87 t ha^{-1}) compared to the genotype OS-6 (55.30 t ha^{-1} and 10.51 t ha^{-1}, respectively). Similar trend followed during first harvest. Only number of shoots per meter row length was significantly higher in JHO-822.

There was non-significant difference between oat genotypes for the contents of important quality parameters viz., crude protein, ether extract, crude fibre and nitrogen free extract. Irrespective of first or second harvest and for total of two harvests, the genotype JHO-822 recorded significantly higher of all the quality parameters.

Effect of seed rate

There was linear and significant increase in green forage yield and dry matter yield during first harvest, second harvest and for total of two harvests with increase in seed rate. The seed rate of 125 kg ha^{-1} produced significantly higher green forage yield (37.20 t ha^{-1} during first harvest, 25.09 t ha^{-1} during second harvest and 62.29 t ha^{-1} total) compared to 75 and 100 kg ha^{-1} seed rate.

Growth parameters per plant were non-significant for seed rate. However, during first and second harvests, number of shoots per meter row length (224.50 and 140.11), fresh weight per meter row length (1237.33 and 398.56 g) and number of seedlings per meter row length (44.33 and 39.33), respectively were significantly higher with 125 kg ha^{-1} seed rate.

There was linear increase in the content of quality parameters with increase in seed rate for crude protein (7.82 and 6.19% during first and second harvests), ether extract (2.25 and 2.49% during first and second harvests) and total ash (9.73 and 9.90% during first and second harvests). While, there was negative relation with increase in seed rate for the contents of organic matter, crude fibre, nitrogen free extract and total carbohydrate.

The seed rate of 125 kg ha^{-1} recorded significantly higher total yield of all the quality parameters with yield of crude protein (843 kg ha^{-1}), ether extract (277 kg ha^{-1}), total ash (4469 kg ha^{-1}), and nitrogen free extract (6623 kg ha^{-1}). Similar trend followed during first and second harvests.

Effect of nitrogen levels

There was linear and significant increase in green forage yield and dry matter yield during first, second harvests and total of two harvests due to successive increase in nitrogen levels upto 150 kg ha^{-1}. The nitrogen level of 150 kg ha^{-1} produced significantly higher green forage yield (38.44 t ha^{-1} during first harvest, 24.14 t ha^{-1} during second harvest and 62.58 t ha^{-1} for total) compared to 90 and 120 kg ha^{-1} nitrogen. The performance of all growth parameters was also significantly higher with 150 kg ha^{-1} nitrogen.

There was linear increase in the contents of quality parameters with increase in nitrogen level for crude protein (7.98 and 6.70% during first and second harvests), ether extract (2.42 and 2.57% during first and second harvests) and total ash (10.06 and 10.33% during first and second harvests) at 150 kg ha^{-1} nitrogen. While, there was negative relation with increase in nitrogen level for the contents of organic matter, crude fibre and total carbohydrates.

The nitrogen level of 150 kg ha^{-1} recorded significantly higher total yield of two harvests for all the quality parameters viz., organic matter (10907 kg ha^{-1}), crude protein (906 kg ha^{-1}), ether extract (302 kg ha^{-1}), crude fibre (2759 kg ha^{-1}), total ash (1248 kg ha^{-1}), nitrogen free extract (6830 kg ha^{-1}) and total carbohydrates (9589 kg ha^{-1}). Similar trend followed during first and second harvests.

Interaction effect

The significantly higher interaction for green forage yield (46.07, 27.77 and 73.83 t ha^{-1} during first harvest, second harvest and total of two harvests, respectively) and dry matter yield (8.75, 5.28 and 14.03 t ha^{-1} during first harvest, second harvest and total of two harvests, respectively) was recorded with interaction $G_2S_3N_3$ *i.e.*, JHO-822 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen.

The interaction $G_2S_3N_3$ also recorded significantly higher performance of growth and yield parameters during first and second harvests *viz.*, plant height (100.67 and 60.37 cm, respectively), number of shoots per meter row length (238.00 and 148.00), number of seedlings per meter row length (45.33 and 40.33), fresh weight per meter row length (1250.00 and 411.00 g) and leaf to stem ratio (2.47 and 0.53).

The next best significantly higher interaction for green forage yield (43.13, 27.35 and 70.49 t ha^{-1} during first harvest, second harvest and total of two harvests, respectively) and dry matter yield (8.20, 5.20 and 13.39 t ha^{-1} during first harvest, second harvest and total of two harvests, respectively) was recorded with interaction $G_1S_3N_3$ *i.e.*, OS-6 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen. This interaction also recorded significantly higher performance of all the growth parameters.

Irrespective of seed rate and nitrogen levels, the interaction $G_1S_1N_1$ i.e., OS-6 with 75 kg ha^{-1} seed rate at 90 kg ha^{-1} nitrogen recorded significantly lower green fodder yield and dry matter yield during first harvest, second harvest and for total yield.

The interaction $G_2S_3N_3$ *i.e.*, JHO-822 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen also recorded significantly higher contents of quality parameters during first and second harvests *viz.*, crude protein (8.28 and 7.12 respectively), ether extract (2.51 and 2.66 respectively) and total ash (11.55 and 11.83 respectively) and significantly lower organic matter (88.45 and 88.17 respectively), crude fibre (17.64 and 28.41 respectively), and total carbohydrates (75.74 and 78.39 respectively).

The total yield of all the quality parameters was also significantly higher in $G_2S_3N_3$ with yields of organic matter (12851 kg ha^{-1}), crude protein (1104 kg ha^{-1}), ether extract (373 kg ha^{-1}), total ash (1697 kg ha^{-1}), nitrogen free extract (7982 kg ha^{-1}) and total carbohydrates (11170 kg ha^{-1}). Similar trend followed during first and second harvests.

Economics

The oat genotype JHO-822 recorded significantly higher, net returns (Rs. 19,587 ha^{-1}) and benefit cost ratio (2.32) compared to OS-6. Higher seed rate of 125 kg ha^{-1} recorded significantly higher net returns (Rs. 22,636 ha^{-1}) and benefit cost ratio (2.53). Higher nitrogen level of 150 kg ha^{-1} nitrogen recorded significantly higher net returns (Rs. 22,020 ha^{-1}) and benefit cost ratio (2.42).

Significantly higher interaction was recorded in $G_2S_3N_3$ *i.e.*, JHO-822 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen compared to rest of the interactions for gross returns (Rs. 44300 ha^{-1}), net returns (Rs. 28774 ha^{-1}) and benefit cost ratio (2.85). The next best interaction for economic advantage was $G_1S_3N_3$ *i.e.*, OS-6 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen.

Conclusion

Oat genotype JHO-822 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen produced significantly higher total green forage (73.83 t ha^{-1}), net returns (Rs. 28,774 ha^{-1}) and benefit cost ratio (2.85) with superior forage quality in northern transition zone under irrigation.

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Appendix I: Prices for inputs and output

Sl. No.	Item	Unit	Price (Rs.)*
A. Inputs			
1	Tractor charges	hr	250
2	Seeds	kg	18
3	Manures and Fertilizers		
	FYM	t	500
	DAP	kg	10.2
	Urea	kg	5.2
	MOP	kg	6.0
4	Labour charges		
	Male (for 8 hr)	day	95
	Female (for 8 hr)	day	85
	Bullock pair with bullock man (8 hr)	day	300
B. Output			
1	Oat green fodder	t	600

* Source MARS, UAS, Dharwad (2010-11)

Appendix II: Requirement of inputs (per ha)

Sl. No.	Particulars	Quantity	Labour	
			Male	Female
1	Land preparation			
	Cultivator (Tractor)	2.5 hr.		
	Harrowing twice (bullock pair)	2.5 hr.		
2	Sowing			
	Seed rate (S_1)	75 kg		
	Seed rate (S_2)	100 kg		
	Seed rate (S_3)	125 kg		
	Bullock pair for sowing & covering	2.5		
3	Fertilizers			
	DAP	130.43 kg		
	Urea	629.49 kg		
	MOP	66.66 kg		
	Labours for application			4
4	Hand weeding (once)			10
5	Intercultivation (once) with bullock pair	2		
7	Green fodder harvesting		20	

Appendix III: Treatment wise details of cost of cultivation (Rs. ha^{-1})

Sl. No.	Particulars	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}	T_{15}	T_{16}	T_{17}	T_{18}
1	**Land préparation**																		
	Cultivator (tractor)	625	625	625	625	625	625	625	625	625	625	625	625	625	625	625	625	625	625
	Harrowing (bullock pair)	625	625	625	625	625	625	625	625	625	625	625	625	625	625	625	625	625	625
2	**Sowing**																		
	Cost of seeds	1350	1800	2250	1350	1800	2250	1350	1800	2250	1350	1800	2250	1350	1800	2250	1350	1800	2250
	Bullock pair for sowing	625	625	625	625	625	625	625	625	625	625	625	625	625	625	625	625	625	625
3	**Manures and Fertilizer**																		
	Cost of FYM	3750	3750	3750	3750	3750	3750	3750	3750	3750	3750	3750	3750	3750	3750	3750	3750	3750	3750
	Cost of fertilizer	2482	2822	3161	2482	2822	3161	2482	2822	3161	2482	2822	3161	2482	2822	3161	2482	2822	3161
	Application charges	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
4	**Hand weeding**	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850
5	**Irrigation**	1140	1140	1140	1140	1140	1140	1140	1140	1140	1140	1140	1140	1140	1140	1140	1140	1140	1140
6	**Intercultivation**	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
7	**Green fodder harvesting**																		
	Labour charges	1700	1700	1700	1700	1700	1700	1700	1700	1700	1700	1700	1700	1700	1700	1700	1700	1700	1700
Total cost of cultivation		13947	14737	15526	13947	14737	15526	13947	14737	15526	13947	14737	15526	13947	14737	15526	13947	14737	15526

RESPONSE OF OAT GENOTYPES TO SEED RATE AND NITROGEN LEVELS ON FORAGE YIELD AND QUALITY UNDER IRRIGATION

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ABSTRACT

Field experiment was conducted at University of Agricultural Sciences, Dharwad in Northern Transition Zone of Karnataka to study the effect of oat genotypes to seed rate and nitrogen levels on forage yield and quality under irrigation during *rabi* 2010-11. The experiment was laid out in randomized complete block design involving two genotypes (JHO-822 and OS-6), three seed rates (75, 100 and 125 kg ha^{-1}) and three nitrogen levels (90,120 and 150 kg ha^{-1}). FYM @ 7.5 t ha^{-1} and nitrogen as per treatments along with 60:40 kg P_2O_5 and K_2O ha^{-1} was applied and crop was harvested twice for green forage at 50 per cent flowering stage. Forage quality parameters were analysed on whole plant dry matter basis.

The oat genotype JHO-822 produced significantly higher total green forage (57.21 t ha^{-1}) and total dry matter (10.87 t ha^{-1}) compared to the genotype OS-6 (55.30 t ha^{-1} and 10.51 t ha^{-1}, respectively). The seed rate of 125 kg ha^{-1} produced significantly higher green forage (37.20 t ha^{-1} during first harvest, 25.09 t ha^{-1} during second harvest and 62.29 t ha^{-1} total) compared to 75 and 100 kg ha^{-1} seed rate. The nitrogen level of 150 kg ha^{-1} produced significantly higher green forage (38.44 t ha^{-1} during first harvest, 24.14 t ha^{-1} during second harvest and 62.58 t ha^{-1} for total) compared to 90 and 120 kg ha^{-1} nitrogen. Significantly higher total green forage yield (73.83 t ha^{-1}), total dry matter yield (14.03 t ha^{-1}) with superior forage quality , net returns (Rs. 28774 ha^{-1}) and benefit cost ratio (2.85) can be obtained with genotype JHO-822 with 125 kg ha^{-1} seed rate at 150 kg ha^{-1} nitrogen.