The Journal of Animal & Plant Sciences, 26(6): 2016, Page: 1718-1724
ISSN: 1018-7081

IMPROVING FORAGE YIELD AND MORPHOLOGY OF OAT VARIETIES THROUGH VARIOUS ROW SPACING AND NITROGEN APPLICATION

M. Irfan[1], M. Ansar[1], A. Sher[2*], A. Wasaya[2] and A. Sattar[2]

[1]Department of Agronomy, PMAS-Arid Agriculture University, Rawalpindi, Pakistan
[2]College of Agriculture, Bahauddin Zakariya University, Bahadur Campus Layyah, Pakistan
[*]Corresponding author's email: ahmad_sher786@yahoo.com

ABSTRACT

Oat is winter season forage crop cultivated throughout the country. It is a fast growing, palatable, succulent and nutritious fodder crop. In this frame, two years field study was carried out at PMAS- Arid Agriculture University Rawalpindi, Pakistan during 2011-12 and 2012-13. It is hypothesized that row spacing and nitrogen (N) application improves morphology and yield forage production of oat varieties. Experiment comprised of four oat varieties (PD_2-LV_{65}, S-2000, NZ0034 and NARC-11) grown under each three N levels (60, 90 and 120 kg ha^{-1}) with row spacing of 12, 24 and 46 cm. Results revealed that var. PD_2-LV_{65} was found more efficient with respect to plant height, number of leaves, biomass traits, green forage yield, dry matter yield and dry matter content than other tested varieties. The highest N rate (120 kg ha^{-1}) significantly affected above parameters than low level (60 kg N ha^{-1}). Higher morphological characters were recorded at 46 cm row spacing while maximum forage yield in narrow row spacing of 12 cm. From these results, we can conclude that var. PD_2-LV_{65} perform better than all the other oat varieties and N application of 120 kg ha^{-1} gave maximum morphological traits and forage yield but row spacing show variable behavior under sub-tropical conditions.

Keywords: Oat varieties, Nitrogen, Row spacing, Forage yield, sub-tropical conditions.

INTRODUCTION

Livestock is a main component of agri-based economy of Pakistan. Its contribution towards GNP is 11.8% which accounts for 56.3% of the agriculture share (GOP, 2014). In rainfed area, livestock progress is very sluggish due to non-availability of forage. Sufficient and nutritious forage directly affect the growth and milk production of animals (Gulrez *et al*., 2007). Therefore, more production of forage is one of the dire needs of the country to conquer the forage scarcity.

Oat is amongst the major winter cereal forages cultivated throughout the country. It is a fast growing, palatable, succulent and nutritive fodder (Nawaz *et al.,* 2004; Alemayehu, 1997). Under favorable conditions oat can provide quality forage from late autumn to mid spring (Stuart *et al.,* 2002; Kim *et al.,* 1996). Oat is mostly fed as green chop while spare is stored as a hey which is used during periods when green fodder is not available (Suttie and Reynolds, 2004).

Oat forage production is affected by different agronomic factors viz., varieties, fertilizer and row spacing. Out yielded forage varieties of crops is the entire need to fulfill the dietary requirements of the animals. High yielding varieties of forage oats produce three-time higher fodder yield as compared to traditional fodder crops (Nawaz *et al.,* 2004). Increasing the nitrogen levels enhanced green forage yield for long period of time. Row spacing is also a key factor for increased forage yield of crop as crop geometry is related with the fertility status and competition for resources so ultimately effect the growth and forage yield. Harvesting stage is very important in forage crop at which crop gives best green forage yield (Kolb *et al.,* 2010; Kristensen *et al.,* 2008; Olsen and Weiner, 2007).

There is great scarcity of green fodder during winter months and farmers feed their animals on dry stalks of kharif crops and grasses. Therefore, to maintain production at high level, it is important to evaluate varieties with more yield potential, high use efficiency of nitrogenous fertilizers by managing it with agronomic practice i.e. row spacing. In present study was planned to evaluate the impact of nitrogen application and row spacing on green forage yield of oat under rainfed condition.

MATERIALS AND METHODS

Site Description: A 2-yr (2011-12 and 2012-13) field studies were carried out on sandy loam soil at University Research Farm (33° 56' N, 72° 52' E), Pir Mehr Ali Shah, Arid Agriculture University, Rawalpindi. The weather data recorded during growing season (URF, Rawalpindi) is presented in Figure 1. Moreover, Soil of the experimental site (0–15 and 15–30 cm) has organic matter (0.75 and 0.50%), available P (7.3 and 7.8), K (120 and 120) mg kg^{-1} with pH (7.6 and 7.5), respectively.

Plant materials: Four oat varieties *viz.*, PD_2-LV_{65}, S-2000, NZ0034 and NARC-11 were approved by Punjab Seed Council in collaboration with Seed Certification and Registration Department. The variety PD_2-LV_{65} is the broader leaves, late duration, high yielding, more nutritious, palatable, multi-cut and disease free varieties. S-2000 is more seed yield, larger seed size and profuse tillering capacity, early maturing. The NARC-11 is a narrow leaves, low yield, small grain size and disease susceptible for rainfed areas and is developed by Pakistan Agricultural Research Council, Islamabad. Variety NZ0034 is more palatability, more stay green, medium plant height and better routoning capacity and is being developed by Renewable Natural Resources Research Centre, Bajo, Wangdue-Bhutan. These varieties were sown under three nitrogen (N) levels (60, 90 and 120 kg ha^{-1}) the whole dose was soil applied at the time of sowing as urea source and dose were applied according to the treatments and row spacing were 12, 24 and 46 cm kept in main, sub and sub-sub plot, respectively. The trial was laid out in Randomized Complete Block Design (RCBD) in split-split plot arrangement with repeated thrice. Seeds of all oat varieties were sown at 85 kg ha^{-1}. A primary dose of phosphorus of 60 kg ha^{-1} was applied in the form of triple super phosphate.

Data Collection: Randomly ten plants were selected from each plot to record the agronomic traits *viz.*, plant height, number of leaves, stem, shoot and root dry weight. For root dry weight, ten randomly selected plants were uprooted from each plot. Root fresh weight was measured after thoroughly washing and then drying these samples in oven at 70°C until the constant weight (AOAC, 1980). Roots samples were taken from top 15 cm soil by digging wet soil through spade. An area of 1 m^2 from each plot was harvested to determine green and dry forage yield at two harvest stages i.e. booting and 50% heading stage.

Statistical Analysis: Calculated data was analyzed by using the Fisher's analysis of variance (ANOVA) techniques and treatment's means were compared using Least Significance Difference (LSD) test at 5% probability level (Steel *et.al.*, 1997).

RESULTS AND DISCUSSION

Plant Height and Number of leaves: Amongst the varieties, PD_2-LV_{65} produced the taller plants (40.3 and 48.3 cm) at booting and 102.2 and 123.8 cm) at 50% heading stage than NARC-11 which produced the dwarf plants of 30 and 38 cm; 74.5 and 95.5 cm, during 2011-12 and 2012-13, respectively (Table-1). Increasing row spacing affected plant height negatively. The N application has significant effect on plant height. Maximum plant height was obtained at higher rate of N (120 kg ha^{-1}) at successive years and stages. Maximum number of leaves per plant of 15.4 and 22.7 vs 40.8 and 43.2 was recorded by var. PD_2-LV_{65} than NARC-11 at successive growth stages and years. Regardless to varieties, row spacing has direct effect on number of leaves. Maximum and minimum were recorded in 46 cm and 12 cm row spacing, respectively (Table 1). The N dosage positively affected number of leaves. The higher dose (120 kg N ha^{-1}) produced more number of leaves as compared to lowest, (60 kg N ha^{-1}) at successive growth stages and years. Plant height and number of leaves per plant are major attributes that involved in the forage yield of crop that associated with growth and biomass. Variation in traits might be due to deflection in cell division and hormonal imbalance caused by the environmental conditions or genetic makeup of varieties (Zaman *et al.*, 2006). These results are in line with the finding of Beyene *et al.* (2015); Lodhi *et al.* (2009); Mekasha *et al.* (2008); Bakhsh *et al.* (2007) who also reported that variation in environmental conditions and genetic makeup cause the variation in plant height and number of leaves. The increase in plant height at narrow row spacing might be due to competition for obtaining light (Steiner, 1986) and may also be the result of severe competition resulting in an increased partition of assimilates to stem and enhances stem elongation (Ballare *et al.*, 1990). The maximum plant height was because of plant enjoying of full benefits of available resources and sunlight as compared to dense population (Rasul *et al.*, 2012). However, Ayub *et al.* (2013) found that no significance difference in plant height and number of leaves with changing the row spacing. In current study, increase the N levels increased the morphological traits. Our results conceded with results of Ahmad *et al.* (2011) and Makhash *et al.* (2008) who narrated that increasing the level of N enhanced the plant height and number of leaves as compare to the low levels of N fertilizer. The increase in plant height with different N levels can be attributed to the fact that N promotes plant growth, increase the number and length of the internodes which results in progressive increase in plant height (Gasim, 2001). While, Henson *et al.* (1999) observed that N application has no significant effect on plant height.

Biomass Traits: Amongst varieties, cv. PD_2-$LV6_5$ produced the maximum biomass traits i.e. stem, shoot and root dry weight per plant than NARC-11. Regardless to varieties, N fertilizer had positive effect on the dry biomass traits (Table 1). The N applied at rate of 120 kg ha^{-1} produced significantly higher above parameters. Row spacing also showed the significant effect on the biomass traits (Table 1). Maximum stem and shoot dry weight was recorded at higher row spacing (46 cm). In contrast, maximum root dry weight was recorded at narrow row spacing (12 cm). Biomass traits i.e. stem, shoot and root dry weight could be the result of more nutrients uptake by the root that is only possible under the dense sown plants which is contradictory under wider row spacing plants. Results of current study in line with the finding of Shangguan *et al.* (2004), Ahmad *et al.* (2011) and Amanullah and Stewart (2013) also narrated that biomass traits are increased with increasing the level of N while opposite association with root penetration.

Green Fodder and Dry Matter Yield: Data regarding mean green forage yield (GFY) of oat varieties is presented in Table 5. Var. PD_2-LV_{65} produced the maximum GFY than NARC-11 at respective stage. The GFY increased with increasing N levels. Maximum GFY was recorded at higher N dose (120 kg ha^{-1}). Similarly, row spacing significantly affected the GFY, maximum GFY (10.5 and 13.7 t ha^{-1}) at booting and (45.8 and 53.9 t ha^{-1}) at 50% heading stage was observed at 12 cm row spacing during both years. Amongst varieties, PD_2-LV_{65} produced maximum dry matter yield (DMY) of 3.6 and 5.5; 19 and 23.6 t ha^{-1} while minimum DMY of 1.4 and 2.6; 11.2 and 15.1 t ha^{-1} was recorded by NARC-11 at booting and 50% heading stage, respectively during consecutive years (Table 2). The N application was also found to be statistically significant on DMY. Maximum DMY at higher N dose (120 kg ha^{-1}), those increased to 58-61% with lower N application (60 kg ha^{-1}). Decreasing row pacing progressively promotes the DMY. Maximum DMY was recorded at 12 cm row spacing than 46 cm row spacing at succeeding growth stages. Significant differences in GFY and DMY among the oat varieties in present study match with the findings of Beyene *et al.* (2015); Hussain *et al.* (2011); Lodhi *et al.* (2009); Ali *et al.* (2003) reported that yield of oat varieties varies due to variation of number of leaves and plant height. More yield of oat varieties might be due to the more adoptability and better performance of that variety (PD_2-LV_{65}) under local agro-ecological conditions than other varieties. Likewise, significant variation among oat varieties were also reported by Gill *et al.* (2013); Amanullah *et al.* (2013). In addition, Mekasha *et al.* (2008) reported that various oat varieties differ significantly in dry matter accumulation that occurs due to the variation in nutrients uptake and environmental condition. Row spacing is another important agronomic practice, which can be used to improve the fodder production of oat. However, different cultivars should be planted considering the plant stature and tillering capacity. For example, dwarf cultivars with low tillering capacity sown in narrowly spaced rows, and cultivars exhibiting lower tillering potential with medium row spacing produced better yield (Hussain *et al.*, 2012, 2013). Findings of the current study highlighted that narrow row spacing improved the fodder production of each tested cultivars due to substantial increase in productive tillers per unit area in both years of study. It might be due to the scarce competition of plants for soil moisture and solar radiation under row spacing (Farooq *et al.*, 2015; Hussain *et al.*, 2016a; Ayub *et al.*, (2013); Pradhan and Mishra, 1994). Therefore, to get higher resource use efficiency and output, dwarf and low tillering cultivars should be planted under narrow row spacing and vice versa (Hussain *et al.*, 2013). Nonetheless, crops sown under wider rows compete with weeds and have higher evapotranspiration, thus resulting in inefficient utilization of applied resources (Ayaz *et al.*, 1999). Higher evaporative losses decrease the WUE due to more available space between crop rows (Farooq *et al.*, 2015; Hussain *et al.*, 2016b). The N has direct effect on GFY and DMY. The current finding indicates that effect of N level are in agreement with the results of Bassegio *et al.* (2013), Mahale *et al.* (2003); Johnston *et al.* (2004), Thakuria and Gogoi (2001). Likewise, Ahmad *et al.* (2011) observed the considerable increase in yield with increasing the level of N. The results are accordance with the findings of Iqbal *et al.* (2013) who also reported that 120 kg N ha^{-1} enhanced the maximum yield of oat crop.

Dry Matter Content: Amongst varieties, PD_2-LV_{65} produced maximum DM content than NARC-11 at respective growth stages. Decreasing row pacing progressively promotes the DM. The maximum and minimum DM content was recorded at 12 and 46 cm row spacing, respectively. The N levels effect on DM. The highest DM of 32.4 and 40.9% was recorded at higher N rate (120 kg ha^{-1}) at successive growth stages. Differences were observed DM content among varieties in present study match with the findings of Kim *et al.* (2006). Increasing the N application enhanced the DM contents in the current study. Wang *et al.* (2002); Iqbal *et al.* (2009) observed that N application significant improved the DM content. In contrast, Bassegio *et al.* (2013) narrated that N application did not showed the significant effect on DM content.

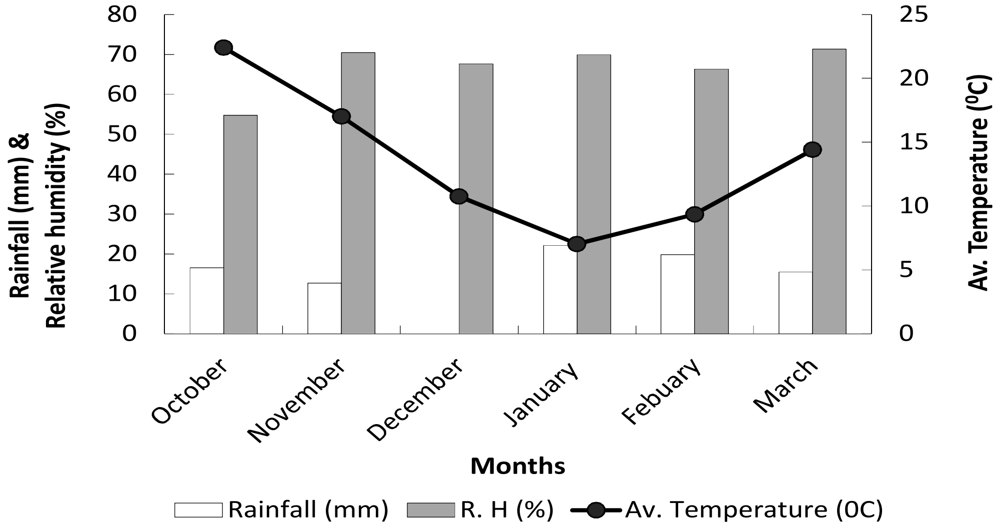

Figure 1. Mean monthly rainfall Av. temperature and RH prevailed for the duration of the crop growth.

Table 1. Effect of variety, nitrogen application and row spacing of oat forage at different growth stages during 2011-12 and 2012-13.

	Plant height (cm)				Number of leaves per plant				Stem dry weight (g)			
Treatments	**Booting**		**50% heading**		**Booting**		**50% heading**		**Booting**		**50% heading**	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Varieties (V)												
PD_2-LV_{65}	40.3^{a}	48.3^{a}	102.2^{a}	123.8^{a}	15.4^{a}	22.7^{a}	40.8^{a}	43.2^{a}	6.8^{a}	8.3^{a}	14.1^{a}	18.9^{a}
S-2000	36.1^{b}	44.0^{b}	92.1^{b}	112.9^{b}	14.5^{b}	19.9^{b}	34.8^{b}	37.0^{b}	6.1^{b}	8.0^{b}	13.0^{b}	17.7^{b}
NZ0034	33.2^{c}	41.3^{c}	87.3^{c}	108.4^{c}	13.6^{c}	16.5^{c}	31.9^{c}	34.1^{c}	6.0^{bc}	7.9^{c}	11.3^{c}	16.0^{c}
NARC-11	30.0^{d}	38.0^{d}	74.5^{d}	95.5^{d}	12.4^{d}	14.3^{d}	26.8^{d}	29.1^{d}	5.8^{c}	7.1^{d}	11.0^{d}	15.7^{d}
LSD	0.65	0.70	1.31	1.46	0.72	0.43	0.68	0.69	0.21	0.20	0.17	0.23
Nitrogen level (N) (kg ha^{-1})												
60	32.6^{c}	41.0c	83.4c	104.5^{c}	11.9^{c}	17.7^{c}	30.2^{c}	32.4^{c}	5.9^{c}	7.0^{c}	10.7^{c}	15.4^{c}
90	35.0^{b}	42.9b	87.9b	108.9^{b}	14.0^{b}	18.4^{b}	34.1^{b}	36.3^{b}	6.1^{b}	7.6^{b}	12.4^{b}	17.1^{b}
120	37.2^{a}	45.2a	95.8a	117.1^{a}	16.1^{a}	18.9^{a}	36.4^{a}	38.6^{a}	6.5^{a}	8.5^{a}	13.9^{a}	18.7^{a}
LSD	0.56	0.61	1.13	1.24	0.63	0.38	0.58	0.60	0.18	0.17	0.15	0.20
Row spacing (RS) (cm)												
12	37.9^{a}	45.8^{a}	92.4^{a}	113.7^{a}	13.0^{c}	17.9^{b}	32.4^{c}	34.5^{c}	5.8^{c}	7.1^{c}	11.8^{c}	16.4^{c}
24	34.5^{b}	42.6^{b}	88.5^{b}	109.6^{b}	13.9^{b}	18.5^{a}	33.1^{b}	35.3^{b}	6.2^{b}	7.6^{b}	12.3^{b}	16.9^{b}
46	32.4^{c}	40.3^{c}	86.2^{c}	107.2^{c}	15.1^{a}	18.6^{a}	35.2^{a}	37.7^{a}	6.6^{a}	8.4^{a}	13.0^{a}	17.8^{c}
LSD	0.56	0.61	1.13	1.24	0.63	0.38	0.58	0.60	0.18	0.17	0.15	0.20

Different letters indicate statistically significant-difference among the values in each column and individual factors (LSD test; $P \leq 0.05$)

Table 2. Effect of variety, nitrogen application and row spacing of oat forage at different growth stages during 2011-12 and 2012-13.

Treatments	Shoot dry weight (g)				Root dry weight (g)				Green fodder yield (t ha^{-1})			
	Booting		50% heading		Booting		50% heading		Booting		50% heading	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Varieties (V)												
PD_2-LV_{65}	6.8 ^{a}	7.2 ^{a}	11.3 ^{a}	16.3 ^{a}	7.4 ^{a}	8.6 ^{a}	10.2 ^{a}	12.7 ^{a}	11.4 ^{a}	14.5 ^{a}	45.5 ^{a}	52.4 ^{a}
S-2000	6.6 ^{b}	6.7 ^{b}	9.8 ^{b}	14.7 ^{b}	6.8 ^{b}	8.2 ^{b}	9.6 ^{b}	12.2 ^{b}	10.4 ^{b}	13.6 ^{b}	43.6 ^{b}	50.3 ^{b}
NZ0034	6.3 ^{c}	6.5 ^{c}	9.0 ^{c}	13.9 ^{c}	6.3 ^{c}	8.0 ^{c}	8.9 ^{c}	11.3 ^{c}	7.9 ^{c}	11.0 ^{c}	35.7 ^{c}	43.5 ^{c}
NARC-11	6.1 ^{d}	6.0 ^{d}	8.8 ^{c}	13.6 ^{d}	6.1 ^{d}	7.7 ^{d}	8.6 ^{d}	11.3 ^{c}	5.7 ^{d}	8.9 ^{d}	33.2 ^{d}	41.0 ^{d}
LSD	0.08	0.14	0.15	0.22	0.12	0.10	0.11	0.18	0.49	0.46	2.02	1.89
Nitrogen level (N) (kg ha^{-1})												
60	6.2 ^{c}	6.2 ^{c}	8.8 c	13.8 ^{c}	6.4 ^{c}	7.8 ^{c}	8.5 ^{c}	11.0 ^{c}	7.1 ^{c}	10.5 ^{c}	31.8 ^{c}	40.0 ^{c}
90	6.5 ^{b}	6.6 ^{b}	9.8 b	14.6 ^{b}	6.7 ^{b}	8.1 ^{b}	9.2 ^{b}	11.7 ^{b}	8.8 ^{b}	11.9 ^{b}	38.0 ^{b}	44.9 ^{b}
120	6.7 ^{a}	7.1 ^{a}	10.6 ^{a}	15.5 ^{a}	6.9 ^{a}	8.4 ^{a}	10.3 ^{a}	13.0 ^{a}	10.6 ^{a}	13.5 ^{a}	48.6 ^{a}	55.4 ^{a}
LSD	0.07	0.12	0.13	0.19	0.10	0.09	0.10	0.16	0.42	0.40	1.75	1.64
Row spacing (RS) (cm)												
12	6.0 ^{c}	6.1 ^{c}	9.2 ^{c}	14.0 ^{c}	7.1 ^{a}	8.4 ^{a}	9.9 ^{a}	12.6 ^{a}	10.5 ^{a}	13.7 ^{a}	45.8 ^{a}	53.9 ^{a}
24	6.5 ^{b}	6.6 ^{b}	9.7 ^{b}	14.6 ^{b}	6.6 ^{b}	8.0 ^{b}	9.4 ^{b}	11.9 ^{b}	8.6 ^{b}	11.7 ^{b}	39.1 ^{b}	46.0 ^{b}
46	6.8 ^{a}	7.1 ^{a}	10.3 ^{a}	15.3 ^{c}	6.2 ^{c}	7.8 ^{c}	8.8 ^{c}	11.1 ^{c}	7.4 ^{c}	10.4 ^{c}	33.5 ^{c}	40.4 ^{c}
LSD	0.07	0.12	0.13	0.19	0.10	0.09	0.10	0.16	0.42	0.40	1.75	1.64

Different letters indicate statistically significant-difference among the values in each column and individual factors (LSD test; $P \leq 0.05$)

Table 3. Effect of variety, nitrogen application and row spacing of oat forage at different growth stages during 2011-12 and 2012-13.

Treatments	Dry matter yield (t ha^{-1})				Dry matter content (%)			
	Booting		50% heading		Booting		50% heading	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Varieties (V)								
PD_2-LV_{65}	3.6 ^{a}	5.5 ^{a}	19.0 ^{a}	23.6 ^{a}	31.3 ^{a}	37.6 ^{a}	41.3 ^{a}	44.6 ^{a}
S-2000	3.1 ^{b}	4.8 ^{b}	17.2 ^{b}	21.5 ^{b}	29.0 ^{b}	35.4 ^{b}	39.0 ^{b}	42.3 ^{b}
NZ0034	2.0 ^{c}	3.4 ^{c}	12.7 ^{c}	16.9 ^{c}	25.1 ^{c}	31.4 ^{c}	35.1 ^{c}	38.4 ^{c}
NARC-11	1.4 ^{d}	2.6 ^{d}	11.2 ^{d}	15.1 ^{d}	23.1 ^{d}	29.3 ^{d}	33.1 ^{d}	36.4 ^{d}
LSD	0.23	0.27	1.11	1.07	0.59	0.61	0.59	0.60
Nitrogen level (N) (kg ha^{-1})								
60	1.9 ^{c}	3.3 ^{c}	11.4 ^{c}	15.6 ^{c}	25.2 ^{c}	31.5 ^{c}	35.2 ^{c}	38.5 ^{c}
90	2.4 ^{b}	4.1 ^{b}	14.3 ^{b}	18.3 ^{b}	26.9 ^{b}	33.3 ^{b}	36.9 ^{b}	40.2 ^{b}
120	3.2 ^{a}	4.9 ^{a}	19.4 ^{a}	23.9 ^{a}	29.3 ^{a}	35.6 ^{a}	39.3 ^{a}	42.6 ^{a}
LSD	0.20	0.23	0.95	0.93	0.51	0.53	0.51	0.52
Row spacing (RS) (cm)								
12	3.2 ^{a}	5.0 ^{a}	18.4 ^{a}	23.4 ^{a}	29.5 ^{a}	35.8 ^{a}	39.5 ^{a}	42.8 ^{a}
24	2.4 ^{b}	4.0 ^{b}	14.8 ^{b}	18.9 ^{b}	27.2 ^{b}	33.5 ^{b}	37.2 ^{b}	40.5 ^{b}
46	1.9 ^{c}	3.3 ^{c}	11.9 ^{c}	15.6 ^{c}	24.7 ^{c}	31.1 ^{c}	34.7 ^{c}	38.0 ^{c}
LSD	0.20	0.23	0.95	0.93	0.51	0.53	0.51	0.52

Different letters indicate statistically significant-difference among the values in each column and individual factors (LSD test; $P \leq 0.05$).

Conclusion: On the basis of two years field investigations clearly indicated that var. PD_2-LV_{65} performed more efficient with respect to plant height, number of leaves, stem, shoot and root dry weight, GFY, DMY and DM content than other tested varieties. Increasing N level (60-120 kg ha^{-1}) significantly increased plant morphology and yield traits. Row spacing showed variations in above parameters. In conclusion, var. PD_2-LV_{65} gave maximum plant morphology and yield traits at N application of 120 kg ha^{-1} but row spacing show variably behavior under sub-tropical condition.

REFERENCES

Ahmad, A.H., A. Wahid, F. Khalid, N. Fiaz, and M.S.I. Zamir (2011). Impact of organic and inorganic sources of nitrogen and phosphorus fertilizers on growth, yield and quality of forage oat (*Avena sativa L.*). Cerc. Agron. Mold. 3(147): 39-49.

Alemayehu, M. 1997. Conservation waste forage development for Ethiopia. Institute for sustainable development. Addis Ababa Ethiopia: 57-60.

Ali, Z., A. Hussain, S. Khan, and M. Bashir (2003). Performance of exotic oats varieties under irrigated conditions of Islamabad. J. Agric. Res. 4:235-238

Amanullah, and B.A. Stewart (2013). Dry matter partitioning, growth analysis and water use efficiency response of oats (*Avena sativa* L.) to excessive nitrogen and phosphorus application. J. Agr. Sci. Technology. 15: 479-489.

AOAC (Association of Official Analytical Chemists), (1980). Official method of analysis. 15th Edition, Washington D.C.

Ayaz, S., P. Shah, H.M. Sharif, and I. Ali (1999). Yield, yield components and other important agronomic traits of wheat as affected by seed rate and planting geometry. Sarhad J. Agric. 15: 255–262.

Ayub, M., G. Haider, M. Tahir, A. Tanveer and M. Ibrahim (2013). Effect of different sowing techniques on growth, forage yield and quality of four oat (*Avena sativa* L.) varieties. Int. J. Modern Agri. 2(4): 152-159.

Bakhsh, A., A. Hussain, S. Khan, Z. Ali, and M. Imran (2007). Variability in forage yield of oats under medium rainfall of pothowar tract. Sarhad J. Agric. 23(4): 867-870.

Ballare, C.L., A.L. Scopel, and R.A. Sanchez (1990). Far-red radiation reflected from adjacent leaves: an early signal of competition in plant canopies. Sci. 247: 329-331.

Bassegio, D., R.F. Antos, E.D. Oliveira, I. Wernecke, D. Secco, S.N. Melegari, and D. Souza (2013). Effect of nitrogen fertilization and cutting age on yield of tropical forage plants. Afr. J. Agric. Res. 8(16): 1427-1432.

Beyene, G., A. Araya and H. Gebremedhn (2015). Evaluation of different oat varieties for fodder yield and yield related traits in Debre Berhan Area, Central Highlands of Ethiopia. Livestock Research for Rural Development. 27, Article #170.

Farooq, S., M. Shahid, M.B. Khan, M. Hussain, and M. Farooq (2015). Improving the productivity of bread wheat by good management practices under terminal drought. J. Agron. Crop Sci. 201: 173-188.

Gasim, S.H. (2001). Effect of nitrogen, phosphorus and seed rate on growth, yield and quality of forage maize (*Zea mays* L.). M.Sc. Thesis, Faculty of Agric. Uni. of Khartoum.

Gill, K.S., A.T. Omokanye, J.P. Pettyjohn, and M. Elsen (2013). Agronomic Performance and Beef cattle nutrition suitability of forage oat varieties grown in the peace region of Alberta, Canada. J. Agric. Sci. 5(7): 128-145.

GOP. (2014-2015). Economic Survey Govt. of Pakistan, Finance Division, Economic Wing. Islamabad. pp. 29.

Gulrez, S., H. Rehman, and M. Sami (2007). Improving forage quality. Dawn, Aug. 2007.

Henson, B., M. McMullen, and B. Schatz (1999). Response of oat varieties to seeding rate and nitrogen fertilizer. https:// www.ag.ndsu.edu/ archive/carringt/99data/oat_seeding_rate.htm

Hussain, A., S. Khan, M.S. Zahid, S. Shafeeq, and Z. Ali (2011). A new high yielding oat variety for fodder in the rainfed potohar and irrigated areas of Pakistan. Sci. Tech. Dev. 30(4): 16-23.

Hussain, M., M. Waqas-ul-Haq, S. Farooq, K. Jabran and M. Farooq (2016a). The impact of seed priming and row spacing on the productivity of different cultivars of irrigated wheat under early season drought. Exp. Agric. doi: 10.1017/ S0014479716000053.

Hussain, M., M.B. Khan, Z. Mehmood, A.B. Zia, K. Jabran, and M. Farooq (2013). Optimizing row spacing in wheat cultivars differing in tillering and stature for higher productivity. Arch. Agron. Soil Sci. 59: 1457–1470.

Hussain, M., S. Farooq, K. Jabran, M. Ijaz, A. Sattar, and W. Hassan (2016b). Wheat sown with narrow spacing results in higher yield and water use efficiency under deficit supplemental irrigation at the vegetative and reproductive stage. Agron. 06:22.

Hussain, M., Z. Mehmood, M.B. Khan, S. Farooq, D.J. Lee, and M. Farooq (2012). Narrow row spacing ensures higher productivity of low tillering wheat cultivars. Int. J. Agric. Biol. 14: 413–418.

Iqbal, M.F., Z. Iqbal, M. Farooq, L. Ali, and M. Fiaz (2013). Impact of nitrogenous fertilizer on yield and quality of oat. Pakistan J. Sci. 65: 1-4.

Iqbal, M. F., M. A. Sufyan, M. M. Aziz, I. A. Zahid, Qamir-ul-Ghani and S. Aslam (2009). Efficacy of nitrogen on green fodder yield and quality of oat (*avena sativa* L.). The J. Anim. Plant Sci. 19(2): 82-84.

Johnston, A.M., G.P. Lafond, F.C. Stevenson, W.E. May, and R.M. Mohr (2004). Effect of nitrogen, seeding date and cultivar on oat quality and yield in the eastern Canadian prairies. Canadian J. Plant Sci. 84:1025-1036.

Kim, D.A., J.K. Kim, C.H. Kwon, W.H. Kim, K.J. Han, and J.L. Kim (1996). Comparative studies of introduced oats for forage production. III. Forage performance of western Australian oat cultivars. J. Kor. Grassl. Sci. 16: 208-214.

Kim, J.D., S.G. Kim, S.J. Abuel, C.H. Kwon, C.N. Shin, K.H. Ko and B.G. Park (2006). Effect of location, season, and variety on yield and quality of forage oat. Asian-Aust. J. Anim. Sci. 19(7): 970-977.

Kolb, L.N., E.R. Gallandt, and T. Molloy (2010). Improving weed management in organic spring barley: physical weed control vs. interspecific competition. Weed Res. 50:597-605.

Kristensen, L., J. Olsen, and J. Weiner (2008). Crop density, sowing pattern, and nitrogen fertilization effects on weed suppression and yield in spring wheat. Weed Sci. 56: 97-102.

Lodhi, M.Y., I.B. Marghazani, K. Hamayun, and M.J. Marri (2009). Comparative performance study of different oat varieties under agro-climatic conditions of Sibi. J. Ani. Plant Sci. 19(1):34-36.

Mahale, B.B., V.B. Nevase, S.T. Thorat, and J.S. Dhekale (2003). Effect of non-symbiotic nitrogen fixers on the forage yield of oat (*Avena sativa* L). Ann. Agric. Res. 24: 121-123.

Mekasha, A., Y.P. Joshi, and A. Mengistu (2008). Effect of nitrogen on morphological characters, yield, and quality of forage oat (*Avena sativa L.*). Commercialization of Livestock Agriculture in Ethiopia. Proceedings of the 16th annual conference of the Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, Ethiopia, October 8 to 10, 2008. Part II: Technical Session. ESAP proceedings.

Nawaz, N., A. Razzaq, Z. Ali, G. Sarwar, and M. Yousaf (2004). Performance of different oat (*Avena sativa L.)* varieties under the agro-climatic conditions of Bahawalpur–Pakistan. Int. J. Agric. Biol. 06(4):624–626.

Olsen, J. and J. Weiner (2007). The influence of Triticum aestivum density, sowing pattern and nitrogen fertilization on leaf area index and its spatial variation. Bas. Appl. Ecol. 8: 252–257.

Pradhan, L. and S.N. Mishra (1994). Effect of cutting management, row spacing and levels of nitrogen on fodder yield and quality of oat. Ind. J. Agron. 39(2): 233-236.

Rasul, F., M. A. Cheema, A. Sattar, M. F. Saleem and M.A. Wahid (2012). Evaluating the performance of three mung bean varieties grown under varying inter-row spacing. The J. Animal and Plant Sci. 22(4): 1030-1035.

Shangguan, Z.P., M.A. Shao, S.J. Ren, L.M. Zhang, and Q. Xue (2004). Effect of nitrogen on root and shoot relations and gas exchange in winter wheat. Bot. Bull. Acad. Sin. 45: 49-54.

Steel, R.G.D., J.H. Torrie, and D.A. Dickey (1997). Principles and procedures of statistics, a biological approach. 3rd Edition. McGraw Hill Book Co., Inc., NY, USA. pp. 352-358.

Steiner, J.L. (1986). Dry land grain sorghum water use, light interception, and growth responses to planting geometry. Agron. J. 78: 720-726.

Stuart, P., J. Slatter, B. Elliott, and G. Busby (2002). The Forage book; a comprehensive guide to forage management (2nd Ed.). Pacific Seeds Pty Ltd., Toowoomba, Australia.

Suttie, J.M. and S.G. Reynolds (2004). Fodder oats.A world over view. FAO,ISBN: 92-5-105243-3. http:/www.fao.org/008/y5765 e/y 5765 e00.htm.

Thakuria, K. and P.K. Gogoi (2001). Performance of oat (*Avena sativa*) in rice (*Oryza sativa*) fallows under different levels of nitrogen and sowing method. Ind. J. Agron. 46(2): 361-363.

Wang, S., Y. Wang, E. Schnug, S. Haneklaus, and J. Fleckenstein (2002). Effects of nitrogen and sulphur fertilization on oats yield, quality and digestibility and nitrogen and Sulphur metabolism of sheep in the Inner Mongolia Steppes of China. J. Nutrient Cycling in Agro Ecosys. 62: 195–202.

Zaman, Q.M., N. Hussain, A. Aziz, and K. Hayat (2006). Performance of high yielding oats varieties under agro-climatic conditions of D. I. Khan. J. Agric. Res. 44: 29-36.