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Sowing Techniques and Cultivars Influence Phenology, Productivity and Profitability of Forage Oat

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Abstract

Sustainable fodder production for an expanding livestock sector has become a challenging task in the backdrop of shrinking land and water resources and uncertainty of climatic optima. Improved crop cultivars in conjunction with optimal sowing methods that ensure better resource utilization resulting in better crop growth and productivity seem indispensable in this regard. Oat (*Avena sativa* L) is an important *Rabi* fodder crop of Pakistan but its fodder productivity is quite low as compared to other countries. Under this study, contribution of sowing methods and cultivars for improvement in water use efficiency (WUE), fodder and crude protein yield of oat at 50% flowering stage was tested. This study was conducted for two years during *Rabi* 2014–2015 and 2015–2016 at Fodder Research Institute Sargodha. Two fodder oat cultivars *i.e*., Sgd.oat-2011 and No-75525 were sown adopting ridge, drill and broadcast methods. Statistical analysis of data on water use, agronomic parameters and economic returns from both cultivars and sowing methods perspective revealed significant differences. Oat cultivar Sgd.oat-2011 performed better than cultivar No.-75525 and among sowing methods ridge sowing technique improved fodder yield by 18.48%. It was found that ridge sowing improved the irrigation efficiency up to 46.16% over broadcasting. Economic analysis showed a maximum benefit-cost ratio of 2.75 for plots where oat cultivar Sgd.oat-2011 was ridge sown. © 2020 Friends Science Publishers

Keywords: Crude Protein; Fodder yield; Oat cultivar; Sowing methods; Water use efficiency

Introduction

Pakistan's agriculture sector plays a pivotal role in its economic growth. Presently, it contributes 19% to Gross Domestic Product (GDP) and employs 42% of the labor force. It is also one of the biggest sectors for earning of foreign exchange and excites the growth of a number of other sectors (Pakistan Economic Survey 2018). Pakistan's agriculture sector is expanding with the recent emergence of other allied sectors and livestock sector is one of the biggest amongst these sectors. It has become increasingly apparent that with a dwindling natural resource base coupled with climate change scenario, the yield potential of crops will be adversely affected. Hence, judicious use of the limited water resources is imperative to enhance the production of fodder and other agronomic crops (Farooq *et al*. 2019).

Huge deficit in demand and domestic production of green fodder exists that needs to be abridged to cope with demand of a fast-growing livestock sector. Livestock being an essential agriculture allied sector shares around 11% in GDP which is 60.54% of agriculture contribution to GDP (Pakistan Economic Survey 2019). Currently, fodder crops are being cultivated on an area of 2.11 million hectares in Pakistan with rich production of 45.77 million tons of green fodder. Punjab contributes 39.20 million tons of fodder from an area of 1.81 million hectares. In Punjab, forage crops rank 3rd after wheat (*Triticum aestivum* L.) and cotton (*Gossypium hirsutum* L.) (Pakistan Economic Survey 2019).

Although fodder shortage is observed round the year; but it becomes more pronounced during May and June, when winter fodders are ending. In November and December, again a shortage is experienced because summer fodders are no longer available at these times. Due to shortage as well as unavailability of good quality fodder, animals remain undernourished with low production. Unawareness of the farmers about high yielding fodder cultivars, unavailability of quality seed, lack of adoption of improved production technologies are the core limitations responsible for low yield of fodder in Pakistan (FRI 2018–2019). The significant gap between demand and production

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of fodder compels for the adoption of new cultivation techniques and high yielding cultivars to overcome this gap.

Cultivation of oat in *Rabi* season has the potential to supply fresh fodder uninterruptedly for 60–70 days during scarcity period. Oat fodder is soft, palatable, and high in crude protein (10–12%). Cultivation of high yielding varieties of oat under improved sowing techniques can maximize fodder production (Nawaz 2017). Mixture of oat and clover (berseem) supplies balanced feed for domestic animals (Younis and Azam 2003). Planting techniques affect the root development and growth of plants by modulating the interplant competition, spatial distribution of plants and acquisition of resources (Shahzad *et al.* 2016; Dabhi *et al.* 2017).

In Pakistan, most of the cultivated area is canal irrigated, where farmers use conventional flood or basin irrigation methods. Under the looming water crisis, flood or basin irrigation is not recommended. Therefore, it is advocated to adopt suitable water saving techniques like bed and furrow irrigation, sprinkler and drip irrigation etc. Bed and furrow irrigation are considered efficient techniques for cultivation fodder crops as these methods increase water use efficiency and decrease water requirement in different cropping patterns (Choudhury *et al.* 2007). These techniques provide efficient drainage of water in waterlogged fields (Sayre and Mreno-Ramos 1997). Raised bed and ridge planting techniques of different crops could save 22% of irrigation water as compared to flat sowing methods (Ali *et al.* 2012). Under the wheat productivity enhancement program (WPEP), it was found that wheat planting on ridges increased yield by 23%. Likewise, 40% water saving over conventional broadcast sowing was also recorded (Akhtar *et al.* 2014).

Present water scarce situation, future prediction of severe water shortage and increased demand of fodder by a fast-growing livestock warrants the need to appraise the performance of improved fodder cultivars and optimize sowing techniques in quest of productivity and profitability. Therefore, the current work has been undertaken to study growth and yield performance of two oat cultivars under three sowing methods.

Materials and Methods

Site description and layout of experiment

The proposed experiment was conducted during *Rabi* season 2014–2015 and 2015–2016 at Fodder Research Institute Sargodha. Climate of the area is temperate characterized as extremely hot in summers and moderate cold in the winters. The maximum temperature reaches 50°C (122°F) in the summer while the minimum temperature recorded is as low as freezing point in the winter. Two fodder oat cultivars *i.e.*, Sgd oat-2011 and No-75525 were sown using ridge, drill and broadcast methods. The experiment was laid out following randomized complete block design (RCBD) with split plot arrangements. Oat cultivars were kept in main plots; while, sowing methods were assigned to sub plots. Experimental treatments were replicated five times with net plot size of 20 m × 9 m.

Crop husbandry

At the commencement of Rabi season, a field vacated by sorghum, was irrigated (10 cm) for pre-soaking of soil before seed bed preparation. When field reached at field capacity (-0.03 MPa), the seed bed was prepared by plowing the soil twice with a tractor mounted cultivator, followed by planking each time. Both cultivars of oat were sown under respective sowing methods as per experimental treatments during 3rd week of October at a seed rate of 80 kg ha^{-1}. For ridge sowing, the oat seed was uniformly broadcasted over the entire field and ridges were made with the help of tractor mounted ridger. For drill sowing, sowing was done with the help of hand drill keeping line to line distance of 30 cm. For broadcasting, the seed was uniformly broadcasted and mixed in to the soil with cultivator. Fertilizer was applied at the rate of 57 kg N ha^{-1} and 57 kg P_2O_5 ha^{-1} using urea and di-ammonium phosphate as fertilizer source. Whole of phosphorus was broadcasted at the time of seed bed preparation; while, all nitrogen was applied with first irrigation after 30 days of sowing. After first irrigation, broad leaved weedicide (bromoxynil + MCPA at 750 mL ha^{-1}) was sprayed at to keep crop free from weeds, and subsequent irrigations were applied according to need of crop.

Procedure for data collection

The data of all agronomic parameters comprising plant height (cm), stem thickness (cm), number of tillers (m^{-2}) number of leaves per tiller, dry matter yield (tons ha^{-1}), number and time of irrigations (min), crude protein and fodder yield (tons ha^{-1}) were recorded following standard procedures. All parameters expect fodder yield, crude protein and dry matter was recorded at 50% flowering. Immediately after harvesting, fresh forage samples from produce of each experimental unit were drawn and weighed thereof. All samples were air dried followed by oven drying at 70°C until a constant weight was obtained. After that fodder and dry matter yield was converted into tons ha^{-1} by unitary method. Then the dried samples were analyzed for crude protein by standard analytical methods after AOAC (1990).

Quantity of irrigation water applied to each treatment was calculated by recording the number and time of total irrigations applied during the season under each treatment. For each irrigation, a cutthroat flume (120 cm × 7.5 cm), installed few meters upstream from the inlet of the experimental plots was used to calculate the inflow rate. Flume readings and time was noted periodically until the flow cutoff. For the purpose of applying the measured quantity of irrigation water, each plot was irrigated

independently. Number of plants per unit area was recorded by averaging two randomly selected samples from the middle of each experimental plot. Plant height from base of plant to the tip of flag leaf was calculated by averaging the height of ten randomly selected plants from each treatment. For stem diameter, ten plants from each treatment were selected randomly and their stem diameters were measured with the help of Vernier caliper and averaged thereof. Influence of various sowing methods and oat cultivars on timing of occurrence of various biological events during the entire crop growth period was investigated. Data on days to emergence and 50% flowering after sowing were recorded and analyzed.

Statistical and economic analysis

The recorded data were statistically analyzed through Fisher's analysis of variance technique using STATISTIX 8.1. Least Significance Difference (LSD) tests were performed at 5% level of probability (Montgomery 2013). Year effect was non-significant; therefore, data of both years were pooled before analysis. Expenditure incurred on all inputs like seedbed preparation, acquisition of seed, fertilizers, water and labor as well as the monetary returns from fresh fodder, dry matter and yield were recorded and analyzed.

Results

Phenology

Significant differences ($P \leq 0.05$) for days to emergence and 50% flowering in response to sowing methods and oat cultivars were observed. Emergence of Sgd-oat-2011 and No -75525 occurred after 9 and 7.8 days of sowing, respectively under ridge sowing, followed by drill sowing with 10.00 and 8.80 days, respectively, while in broadcast method emergence of these cultivars was observed after 11.60 and 10.40 days, respectively (Table 1).

Similarly, 50% flowering in both cultivars *i.e*., Sgd-oat-2011 and No -75525 was observed after 116.8 and 98.2 days of sowing, respectively under ridge sowing followed by drill sowing with 113.6 and 93.0 days, respectively. Whereas, Sgd-oat-2011 and No-75525 required lowest number of days to flowering *i.e*., 109.6 and 88.4 days, respectively when these were sown using broadcast method (Table 1). Thus, it is concluded that minimum number of days to emergence was observed in Cultivar No-75525 when sown on ridges; while, maximum number of days to flowering was observed for cultivar Sgd-oat-2011under same sowing method. It seems that ridge sowing is the best method regarding cop phonological development, and cultivar No-75525 showed early commencement of different phonological stages.

Growth parameters

Interactive effect of sowing methods and oat cultivars on growth, yield parameters and water saving were recorded during the course of present studies. The results showed significant differences ($P \leq 0.05$) among tested treatments for all growth and yield parameters as well as irrigation water savings. Data revealed that highest values of number of tiller (297.40 m^{-2}), plant height (112.2 cm), leaves per tiller (9.2) and stem thickness (0.82 cm) were observed for plants of cultivar Sgd-oat-2011 sown under ridge sowing method, followed by drill sowing method with values of 275 m^{-2}, 103.4 cm, 135.94 cm^2, 8.2 and 0.66 cm, respectively for aforementioned parameters; whereas, lowest values were observed when both of the oat cultivars were sown by broadcasting method (Table 2).

Yield and quality traits

The results revealed that interactive effect of treatments showed significant influence ($P \leq 0.05$) on production of fresh biomass (fodder), dry matter and crude protein (Table 3). Highest quantities of fresh fodder (83.3 t ha^{-1}), dry matter, (16.86 t ha^{-1}), crude protein (2.59 t ha^{-1}) and crude protein contents (15.4%) were recorded for experimental plots of cultivar Sgd-oat-2011 sown on ridges, followed by drill sown plots (77.92 t ha^{-1}), (15.64 t ha^{-1}), (14.19 t ha^{-1}) and (14.53%), respectively of the same cultivar. The lowest yields were observed under broadcasting sowing method (Table 3). For cultivar No-75525, highest fresh fodder yield (66.31 t ha^{-1}), dry matter (11.105 t ha^{-1}) and crude protein (1.56 t ha^{-1}) were observed when it was sown through ridge sowing and minimum fodder yield (55.60 t ha^{-1}) was recorded from fodder crop sown under broadcasting method (Table 3).

Irrigation water saving

While applying irrigation, constant discharging outlet was used to divert irrigation water to each treatment. Only the time of irrigation varied, thus irrigation opportunity was recorded for every irrigation in each treatment. Total time of irrigation during entire crop season to each treatment was noted (Table 4). It was found that 43.75 and 46.45% more time was recorded for irrigating the drill and broadcast sown plots of oat, respectively as compared to the ridge sown plots. Thus, the ridge sowing method saves irrigation water to the tune of 43.75 and 46.45% comparing with drill sowing and broadcasting, respectively.

Economic analysis

The economic analysis carried out on the basis of fresh green fodder yield revealed that oat fodder crop sown under ridge sowing gave maximum net return of Rs. 119225 ha^1 followed by drill sowing (Rs. 99970 ha^{-1}) and broadcasting (Rs. 92445 ha^{-1}) (Table 5). Benefit-cost ratio for ridge sowing was highest (2.75) followed by drill sowing and broadcasting (Table 5).

Table 1: Effect of sowing methods on number of days to emergence and 50% flowering of oat varieties (values are means of two years)

Sowing methods/cultivars	Days to emergence (days)		Days taken to 50% flowering (days)	
	Sgd.oat-2011	No-75525	Sgd.oat-2011	No-75525
Ridge sowing	9.0 ± 0.71 c	7.8 ± 0.84 d	116.8 ± 2.39 a	98.2 ± 2.39 d
Drill sowing	10.0 ± 0.71 b	8.8 ± 0.84 c	113.6 ± 2.7 b	93.0 ± 2.24 e
Broadcasting	11.6 ± 0.5 a	10.4 ± 0.55 b	109.6 ± 2.4 c	88.4 ± 2.30 f
LSD at $P \leq 0.05$	1.00		3.31	

Means ± standard deviation not sharing same letters, with in a column or row for each trait, differ significantly from each other at $P \leq 0.05$

Table 2: Effect of sowing methods on growth parameters of forage oat varieties (values are means of two-year data)

Sowing methods/cultivars	Number of tillers (m^{-2})		Plant height (cm)		Number of leaves per tiller		Stem diameter (cm)	
	Sgd. oat-2011	No-75525	Sgd. oat-2011	No-75525	Sgd. oat-2011	No-75525	Sgd. oat-2011	No-75525
Ridge sowing	297.4 ± 10.69 a	279.0 ± 9.62 b	112.2 ± 3.35 a	102.4 ± 3.78 b	9.0 ± 0.84 a	8.6 ± 1.14 ab	0.82 ± 0.08 a	0.78 ± 0.13 a
Drill sowing	275.0 ± 11.18 b	261.0 ± 8.48 c	103.4 ± 4.72 b	98.6 ± 3.13 c	8.2 ± 1.09 a-c	8.0 ± 0.71 a-c	0.66 ± 0.11 b	0.60 ± 0.12 b
Broadcasting	248.2 ± 8.84 d	234.2 ± 5.49 e	99.0 ± 3.39 c	93.8 ± 3.96 d	7.6 ± 1.14 bc	7.2 ± 0.84 c	0.54 ± 0.09 c	0.52 ± 0.08 c
LSD at $P \leq 0.05$	9.42		1.86		1.45		0.11	

Means ± standard deviation not sharing same letters, with in a column or row for each trait, differ significantly from each other at $P \leq 0.05$

Table 3: Effect of sowing methods on fodder yield, dry matter, crude protein yield and contents of oat varieties (values are means of two-year data)

Sowing methods/cultivar	Fodder yield (t ha^{-1})		Dry matter yield (t ha^{-1})		Crude protein yield (tons ha^{-1})		Crude protein contents (%)	
	Sgd. oat-2011	No-75525	Sgd. oat-2011	No-75525	Sgd. oat-2011	No-75525	Sgd. oat-2011	No-75525
Ridge sowing	83.3 ± 1.94 a	66.3 ± 3.10 d	16.9 ± 0.37 a	11.1 ± 0.36 d	2.59 ± 0.29 a	1.56 ± 0.20 d	15.4 ± 0.08 a	14.1 ± 0.08 d
Drill sowing	77.9 ± 1.67 b	59.4 ± 1.4 e	15.6 ± 0.38 b	10.0 ± 0.38 e	2.30 ± 0.25 b	1.37 ± 0.20 e	14.5 ± 0.1 b	13.8 ± 0.1 e
Broadcasting	70.6 ± 2.1 c	55.6 ± 1.95 f	14.2 ± 0.5 c	9.3 ± 0.31 f	2.06 ± 0.31 c	1.25 ± 0.27 f	14.5 ± 0.03 c	13.4 ± 0.1 f
LSD at $P \leq 0.05$	2.44		0.18		0.05		0.10	

Means ± standard deviation not sharing same letters, with in a column or row for each trait, differ significantly from each other at $P \leq 0.05$

Table 4: Effect of sowing methods on time for irrigation to oat varieties (values are means of two years data)

Sowing methods	Time for irrigation (min ha^{-1})		Increase in time over ridge sowing (%)	
	Sgd. oat-2011	No-75525	Sgd. oat-2011	No-75525
Ridge sowing	255 ± 6.36 d	254 ± 7.57 d	-	-
Drill sowing	368 ± 7.02 bc	366 ± 6.91 c	44.31	44.09
Broadcasting	372 ± 8.80 a	372 ± 5.07 ab	45.88	46.46
LSD at $P \leq 0.05$	4.24			

Means ± standard deviation not sharing same letters, with in a column or row for each trait, differ significantly from each other at $P \leq 0.05$

Table 5: Economic comparison of different sowing methods

Treatments	Cultivation cost (Rs. ha^{-1})		Gross returns (Rs. ha^{-1})		Net returns (Rs. ha^{-1})		Benefit: cost ratio	
	Sgd. oat-2011	No-75525	Sgd. oat-2011	No-75525	Sgd. oat-2011	No-75525	Sgd. oat-2011	No-75525
Ridge sowing	67925	67925	208250	165750	140325	97825	3.06	2.44
Drill sowing	70395	70395	194750	148500	124355	78105	2.76	2.11
Broadcast sowing	65455	65455	176500	139000	111045	73545	2.69	2.12

Discussion

In the present study, two oat cultivars (Sgd-oat-2011 and cultivar No-75525) were cultivated using three different sowing methods (*i.e.*, ridge, drill and broadcast). Their interactive effect was evaluated for optimizing fodder production and saving irrigation water. Statistical analysis of data recorded on various agronomic and yield parameters and water use showed significant variations. Significant effect of sowing techniques and cultivars used under this experiment was observed on number of days to emergence, days to 50% flowering, growth and yield parameters and water saving. Differences in days to emergence and 50% flowering, most probably and predominantly was due to differences in genetic makeup of the cultivars. However, it could be postulated that sowing techniques had their own impact in providing favorable environment for root development and nutrient acquisition for quick germination which resulted in early commencement of seed germination and prolonged period of vegetative growth for better production. Sowing techniques have been reported to influence nutrients acquisition and utilization and provide a greater number of days for vegetative growth that positively affected the growth attribute (Bakht *et al*. 2006, 2007, 2011). Oat cultivars took lowest number of days to 50% flowering under broadcast sowing was mainly due to increase in intra-plant competition and crowding between

neighboring plants which is in full agreement with findings of Ali *et al*. (2012). Some earlier researchers indicated enhancement in crop growth and yield attributes by ridge sowing method and cultivars (Kabesh *et al.* 2009; Ao *et al.* 2010; Belachew and Abera 2010; Nawaz 2017). Under the current investigation, ridge sowing improved the growth parameters like number of tillers m^{-2}, plant height (cm), number of leaves per tiller, stem diameter (cm) etc., which is in full agreement with previous researches. This might be due to improvement in soil structure that enhanced the aeration, water and nutrient uptake, better growth environment and increased nutrients availability and uptake (Arif *et al.* 2001; Abdullah *et al.* 2008; Khan *et al.* 2012). Increased fodder yield, dry matter and crude protein yield with higher crude protein contents were obtained in cultivar Sgd-oat-2011 as compared to No-75525 (Table 5 and 6). This might be due to inherent differences and maximum vigor in growth parameters (Jha *et al*. 2012; Ratan *et al*. 2016; Dabhi *et al.* 2017). Improvement of fresh fodder yield, dry matter and crude protein yield including crude protein contents was presumably because of efficient light and nutrient utilization, improved aeration and irrigation by plants as reported by Sharma and Bhunia (2001); Soomro *et al*. (2009) and Hameed *et al*. (2014).

In context of above discussions and findings, ridge sowing can be opted as an optimized and beneficial technique to achieve better fodder, dry matter and crude protein yield of oat cultivar Sgd-oat-2011. Comparison of cultivars indicated that Sgd-oat-2011 produced higher fodder, dry matter and crude protein yield as compared to cultivar No-75525 due to genetic differences and maximum vigor in growth parameters (Roshan *et al*. 2012; Godara *et al*. 2016).

Considering the irrigation water saving, it is obvious that least time of irrigation was recorded for ridge sowing. This is due to the fact that under this sowing technique, less surface area had to be soaked; thus, less irrigation opportunity time was required to irrigate the reduced surface area. On the other hand, water uptake is increased due to direct application to the roots in the presence of loose fertile layer. Availability of favorable moisture enhances the nutrient uptake required for development of better root system which contributes towards high leaf area index (data not given). Higher leaf area received more solar radiation used for photo-assimilation, resulting in higher crop vigor and growth rate (CGR) (Rasheed *et al.* 2003; Hussain *et al*. 2010). Ridge sowing method helps to maximize water savings, increase water use efficiency, enhance yield, save time of irrigation and reduced energy costs for water pumping (Ahmad and Mahmood 2005; Majeed *et al*. 2015; Hussain *et al*. 2018).

Maximum benefit-cost ratio recorded for ridge sowing was due to high yield and less cost of production including saving of water as compared to drill sowing and broadcasting methods (Hussain *et al.* 2015).

Conclusion

Fodder oat cultivar Sgd.oat-2011 sown on ridges gave the best quality fresh fodder with the highest economic returns. Ridge sowing method increases water use efficiency, nutrient uptake, saves irrigation water and improves drainage while heavy rain fall during late oat sowing season. Education and awareness of farming community is required to adopt oat cultivar Sgd.oat-2011 for better productivity and economic returns; while, ridge sowing technique should be promoted to save irrigation water, to increase water use efficiency and to enhance nutrient uptake by the crop.

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Author Contributions

MRG and AH conceived idea, planned and executed the experiment, AR, AM and AH collected and recorded data, WN statistically analyzed the data and made illustration, MRG, MSH and AH drafted the manuscript, SAR interpreted the results, reviewed the contents and finalized the manuscript in its present shape.

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