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MOISTURE STRESS AND SEEDING DENSITIES EFFECT ON PHENOLOGY, GROWTH AND NET ASSIMILATION RATE OF WHEAT (*TRITICUM AESTIVUM* L.).

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ABSTRACT

A field experiment pertaining to growth, water use efficiency and final yield of wheat crop under various irrigation regimes and seeding densities was conducted at Agronomic Research Farm, University of Agriculture, Faisalabad during growing season of 2011-12. Layout system was RCBD with split plot arrangement keeping three replications and a net plot size of 1.2 m × 8.0 m. Irrigation regimes were allotted in main plots while seeding rates were randomized in sub plots. The trial comprised four irrigation treatments viz. I_1 = irrigation water applied at all critical growth stages (tillering + booting + anthesis + grain formation stages), I_2 = irrigation water applied at booting, anthesis and grain ali formation stages, I_3 = irrigation applied at tillering, booting and grain filling stages and I_4 = water applied at tillering, booting and anthesis growth stages and three seeding rates i.e. 100 kg (SR_1), 125 kg (SR_2) and 150 kg (SR_3) per hectare. The results indicates that thermal time taken by wheat crop to attain physiological maturity was 1423.75 degree days in I_1, 1322.5 degree days in I_2 and 1345.5 degree days in I_3 and 1345.5 degree days in I_4.The application of irrigation water at tillering, booting, anthesis and grain formation stages (I_1) resulted in higher total dry matter production (1626.5g/m^2) and net assimilation rate (4.07g/m^2/day). Similarly higher total dry matter production (1217.6g/m^2) and maximum NAR (3.45 g/m^2/day) was also recorded by application of seed @ 150 kg per hectare.

Key words: Wheat; *tricum aestivum;* thermal time; leaf area duration; seeding rate, anthesis; Pakistan.

INTRODUCTION

Moisture scarcity adversely influenced on plant vigor, establishment and final harvest of wheat crop, particularly it affects cell enlargement and growth expansion (10, 11). Moisture sensitivity also decreased the water content,

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water potential of leaves, cell elongation, and plant vitality and caused stomatal closure. Severe moisture stress resulted in inhibition of photosynthesis, metabolic disturbance and finally led to the loss of plant (9,13)..Maximizing the number of irrigation were associated with markedly increasing in leaf area index (LAI), crop growth rate (CGR), net assimilation rate (NAR), number of productive tillers, grains per spike, seed size and harvest index. Among irrigation scheduling, irrigation water at tillering, booting, anthesis, grain formation and dough stages gave maximum values for net assimilation rate and final harvest index (1, 12).

Seeding rate is major yield determining element of crop. The use of recommended seed rate is essential for optimum plant population i.e. number of plant per unit area. Higher seeding rate significantly enhanced leaf and shoots vigor per unit area, leaf area index, dry matter accumulation, crop growth rate and finally grain yield. Planting density also produces largest canopy cover that increases interception of solar radiation. Planting density is important parameter and can significantly affect the germination percentage, growth, development, phenology and final yield of wheat (15, 5) observed that crop planted with 200 kg per hectare seeding rate showed better plant vigor and productivity. Hussain *et al*. (7, 8) concluded that effect of seed rates was significant on most of agronomic traits of tested varieties. Crop growth rate, leaf area index, net assimilation rate, photosynthetic efficiency, protein content, tillers per meter square and leaf fresh weight were high at higher seeding rate (200 kg/ ha).

MATERIALS AND METHODS

This study was conducted at Agronomic Research Farm, University of Agriculture, Faisalabad during growing season of 2011-12 during the year 2011-12. The area is selected at latitude 31.25 ^{0}N, longitude 73.06 ^{0}E and altitude184.4 m. Before sowing of crop, a composite soil sample was obtained at the 25 cm depth from experimental area with soil auger. The sample was analyzed for various physiochemical properties. The soil of experimental site was sandy clay loam in nature. Layout system was RCBD with split plot arrangement keeping three replications. The moisture stresses were randomized in main plots while seed rates in sub plots. The net plot size was 1.2 m × 8.0 m with 20 cm apart rows. The study included four irrigation levels viz. I_1 = No stress (irrigation at tillering, booting, anthesis and grain formation stages), I_2 = Stress at tillering stage (irrigation at booting, anthesis and grain formation stages), I_3 = Stress at anthesis stage (irrigation at tillering, booting, grain formation stages) and I_4 = Stress at grain formation stage (irrigation at tillering, booting, anthesis stages) while there seed rates i.e. 100 kg (SR1), 125 kg(SR_2),and 150 kg (SR3) per hectare were tried.

"Rouni" irrigation was applied to the field 15 days before sowing of crop, to maintain soil moisture at field capacity. Ploughing was done two times followed by planking to prepare fine seed bed for wheat sowing. The crop was planted on November 22, 2011 with help of single row hand drill. Net plot size was 1.2 m × 8.0 m and row × row distance was maintained at 20 cm. Fertilizer was applied @ 120-90-75 kg NPK per hectare using urea, di-ammonium phosphate (DAP) and sulfate of potash (SOP) as the sources. Phosphorus and Potash fertilizers were used during sowing time. Nitrogen doses were applied in two splits i.e. half N at sowing time and remaining at booting stage. All agronomic practices were kept uniform for all treatments.

Table 1. Crop husbandry operations for the field experiment

Operations	**Date**
Sowing time	22 Nov. 2011
Phenology	
Tillering stage	07 Jan. 2012
Stem elongation stage1	17 Jan. 2012
Booting stage	05 Feb. 2012
Heading stage	14 Feb. 2012
Anthesis stage	27 Feb. 2012
Grain formation stage	13 March 2012
Physiological maturity stage	12 April 2012
Harvesting time	01 May 2012

Table 2. Irrigation schedule of wheat for different treatments.

Irrigations	**Schedule of irrigation in (mm)treatments**				
	Dates	I_1	I_2	I_3	I_4
1^{st}	07 Jan. 2012	75	-	75	75
2^{nd}	05 Feb. 2012	75	75	75	75
3^{rd}	27 Feb 2012	75	75	-	75
4^{th}	13 March 2012	75	75	75	-
Rainfall (mm)		14.2	14.2	14.2	14.2
Total		314.2	239.2	239.2	239.2

Calculation of the amount of water applied

The discharge of water was calculated according to Chaudhary et *al.* (2) by the help of cut throat flume

$$t = \frac{A \quad x \quad d}{Q}$$

Here *t* is time to irrigate taken in seconds, *A* will be the area to be irrigated (m^2), *d* will be the depth of water (m) and *Q* is the discharge of cut throat flume taken (m^3).

The experimental area was divided equally; one was kept for final harvest while other was used for crop growth analysis. The sampling was started after 30 days of sowing while plant growth sampling was started at the interval of 15 days upto the physiological maturity of crop. Regular field visits were maintained to check the emerged seedlings according to the seedling evaluation Hand Book of Association of Official Seed Analysts.

Mean emergence time (days)

After completion of emergence the mean emergence time (MET) was measured following Ellis and Roberts (3) and Noorka *et al*., (12).

$$MET = \frac{\sum DN}{\sum N}$$

Whereas, number of seeds, which were emerged on day D while D = number of days counted from the beginning of emergence.

Crop development

All developmental stages were considered when 50 percent of plants showed visual signs of the stage being considered. Five plants were selected randomly from each treatment of each replication. These plants were tagged and assigned a number to each selected plants for recording data regarding phenological development of plants like, days to emergence, days to tillering, days to stem elongation, days to booting, days to anthesis and Days to maturity. Thermal time (growing degree days) was estimated according to Gallagher *et al.* (4). It calculates thermal time (Tt) as a function of mean temperature above a base temperature (Tb).

$$GDD = \frac{T_{max} + T_{min}}{2} \quad T_{base}$$

Here T_b is base temperature taken as 5°C for wheat.

Leaf area duration (days): The leaf area duration (LAD) describes the duration during which leaf remained green. Leaf area duration was estimated from LAI by Hunt method (6).

$$LAD = \frac{(LAI_1 + LAI_2) \times (t_2 - t_1)}{2}$$

Here LAI_1 and LAI_2 are the leaf area indices at times t_1 and t_2, respectively. Cumulative LAD at final harvest was calculated by adding all LADs values.

An area of 4 m^2 was harvested from each plot of each replication at random. The harvested crop was tied into bundles and then sun dried for a period of about one week in the respective plots. Total dry matter of sun dried samples was recorded for each treatment with the help of a spring balance. The total dry matter per plot was calculated and then it was converted into tons per hectare.

Net assimilation rate (g/m^2/day)

Net assimilation rate (NAR) is the ratio of total dry matter and leaf area duration. The average net assimilation rate is estimated using the formula of Hunt (6).

$$NAR = \frac{TDM}{LAD}$$

TDM and LAD were the total dry matter and leaf area duration respectively at final harvest. All weather data for the whole crop growth period were obtained from nearest metrological observatory closed to the experimental area in Department of Crop Physiology, University of Agriculture, Faisalabad.

Statistical analysis

Data were collected using standard procedures and techniques on growth, biomass, water use efficiency and yield. All the data obtained were analyzed using Fisher's analysis of variance technique (14) and treatments' means by using the least significant difference (LSD) test at 5 percent probability level.

RESULTS AND DISCUSSION

Mean emergence time (MET)

The (Table 3) exhibited that mean emergence time was significantly influenced by different seeding rates but showed non-significant difference regarding irrigation regimes. It was observed that peak value of MET (10.09 days) was found of treatment SR_3 (150 kg seed/ ha Table 3 which was statistically at par with SR_2 (9.67 days). Plots seeded at SR1 took considerably minimum MET (8.75 days).

Table 3. Effect of irrigation scheduling and seeding rates on mean emergence time (days) in wheat.

Treatments	Seeding Rate			
Irrigation level	SR_1 (100 kg/ha)	SR_2 (125 kg/ha)	SR_3 (150 kg/ ha)	Mean
I_1	9	10	10.67	9.89
I_2	9	9.67	10	9.56
I_3	8.67	9.67	10	9.45
I_4	8.33	9.33	9.67	9.11
Mean	8.75 b	9.67 a	10.09 a	

Means not sharing a common letter differ significantly at $p \leq 0.05$, LSD value for seed rate = 0.81

Overall average value of mean emergence time was noted as 9.47 days during the growing season. The interactive effect of irrigation levels and planting rates was non-significant regarding MET.

The data on developmental timing of various growth stages from sowing to maturity of spring wheat crop exhibited that sowing was done at 22nd November 2011 and seed germination was completed between 1st and 4th December (Table 4a). The number of days for germination was 11 in case of treatment I_1 (irrigation water at tillering + booting + anthesis + grain formation stages), 10 in I_2 (moisture stress imposed at tillering stage), again both I_3 (stress applied at anthesis stage) and 10.33 in I_3 (water stress at grain formation stage) (Table 4b). Tillering was recorded on 2nd to 7th January (Table 4a).

Table 4(a). Calendar time (dates and days) for different developmental stages of wheat under various irrigation scheduling and seeding rates.

Stages	(a) Calendar Time (dates)			
	SR_1			
	I_1	**I_2**	**I_3**	**I_4**
Sowing	22.11 .2011	22.11. 2011	22.11 2011	22. 11. 2011
Germination	02.12.2011	01.12. 2011	01.12.2011	01.12. 2011
Tillering	04.01.2012	02.01. 2012	04.01.2012	03.01. 2012
Stem Elongation	15.01.2012	13.01. 2012	14.01.2012	15.01. 2012
Booting	03.02.2012	01.02. 2012	04.02.2012	03.02. 2012
Anthesis	25.02 2012	24.02 2012	23.02 2012	25.02 2012
Grain Formation	11.02.2012	12.03. 2012	10.03.2012	10.03. 2012
Maturity	14.04 2012	09.04 2012	10.04 2012	10.04 2012
Harvest	01.05 2012	01.05 2012	01.05 2012	01.05 2012
	SR_2			
Sowing	22.11.2011	22. 11. 2011	22.11.2011	22.11. 2011
Germination	03.12.2011	02.12. 2011	02.12.2011	03.12. 2011
Tillering	05.01.2012	04.01. 2012	06.01.2012	05.01. 2012
Stem Elongation	16.01.2012	14.01. 2012	16.01.2012	15.01. 2012
Booting	04.02.2012	02.02. 2012	03.02.2012	03.02. 2012
Anthesis	26.02 2012	24.02 2012	24.02 2012	26.02 2012
Grain Formation	12.03.2012	11.03. 2012	11.03.2012	11.03. 2012
Maturity	13.04 2012	10.04 2012	09.04 2012	09.04 2012
Harvest	01.05 2012	01.05 2012	01.05 2012	01.05 2012
	SR_3			
Sowing	22. 11. 2011	22.11. 2011	22.11. 2011	22.11. 2011
Germination	04.12. 2011	03.12. 2011	03.12. 2011	03.12. 2011
Tillering	07.01. 2012	05.01. 2012	06.01 .2012	06.01. 2012
Stem Elongation	17.01. 2012	15.01. 2012	17.01. 2012	16.01. 2012
Booting	05.02. 2012	03.02. 2012	05.02. 2012	05.02. 2012
Anthesis	27.02 2012	26.02 2012	25.02 2012	27.02 2012
Grain Formation	13.03. 2012	12.03. 2012	11.03. 2012	12.03. 2012
Maturity	15.04 2012	08.04 2012	11.04 2012	11.04 2012
Harvest	01.05 2012	01.05 2012	01.05 2012	01.05 2012

Tillering stage took 44.33 DAS in treatments I_1, 42.67 DAS in I_2, 44.67 DAS in case of treatment I_3 and 43.67 DAS in $I_{4,}$ (Table 4b). Stem elongation stage was appeared on 13th, 14th, 15th, 16th and 17th January for all treatments (Table 4a). In treatments I_1, I_2, I_3 and $I_{4,}$ booting growth stage was completed on 74 DAS, 72 DAS, 74 DAS and 73.68 DAS, respectively (Table 4b). The data (Table 4a) further showed that Anthesis stage was started on 23th February and completed upto 27th February. It took 96 DAS in I_1 treatment, 94.68 DAS in I_2 treatment, 94 DAS in I_3 and again 96 DAS in I_4 treatment (Table 4b). Similarly, grain formation stage was completed on 111, 110.6, 109.67and 110.33 DAS in treatments I_1, I_2 I_3 and I_4, respectively (Table 4b). Wheat crop reached at physiological maturity between 8^{th} to 15^{th} April and took 144 DAS regarding I_1 treatment, 139 DAS in $I_{2,}$ 140 DAS in case of treatment I_3 and 140 DAS in I_4 treatment, respectively (Table 4 b). Similar results were reported by Noorka and Khaliq, (11) and Noorka *et al.,* (12).

4 (b). Calendar time for different developmental stages of wheat under various irrigation scheduling and seeding rates.

Stages	(a) Calendar Time (days)											
	SR1				SR2				SR3			
	I1	I2	I3	I4	I1	I2	I3	I4	I1	I2	I3	I4
Sowing	0	0	0	0	0	0	0	0	0	0	0	0
Germination	10	09	09	09	11	10	10	11	12	11	11	11
Tillering	43	41	43	42	44	43	46	44	46	44	45	45
Stem Elongation	54	52	53	54	55	53	55	54	56	54	56	55
Booting	73	71	74	73	74	72	73	73	75	73	75	75
Anthesis	95	94	93	95	96	94	94	96	97	96	95	97
Grain Formation	110	111	109	109	111	110	110	110	112	111	110	112
Maturity	144	139	140	140	143	140	139	139	145	138	141	141
Harvest	161	161	161	161	161	161	161	161	161	161	161	161

I_1 = Irrigation applied at tillering, booting, anthesis and grain formation stages, I_2 = Stress imposed at tillering stage, I_3 = Stress imposed at anthesis stage, I_4 = Stress at imposed grain formation stage SR_1 = 100 kg/ha, SR_2 = 125 kg /ha, SR_3 = 150 kg /ha

Leaf area duration (days)

Leaf area duration (LAD) in case of I_1 (plots irrigated with full irrigation at all critical growth stages) was considerably maximum (399.88 days) as compared to other treatment means. Irrigations water was skipped at anthesis stage in I_3 and at grain development growth stage in I_4 produced the lowest LAD i.e. (315.63 and 322.45 days) respectively. On the other hand, significantly average number of LAD (356.79 days) were obtained where irrigation applied at booting, anthesis and grain filling stages and skipped at tillering growth stage. So it was concluded that wheat plant diminished their LAD when plants not irrigated at anthesis and grain formation stages (322.45 days and 315.63 days). In relation to seeding rates means, there was also found non-significant difference in LAD regarding various growing rates. It was further seen that LAD remained statistically at par in all treatments. Seeding rate of 125 kg/ha (SR_2) produced maximum LAD (351.71 days) followed by treatment SR_3 (351.31 days) and SR_1 (343.03 days). The results supported the finding of earlier scientists (1, 5, 7, 8, 15, 16) under same environmental conditions.

The interaction effect of irrigation levels and seed rates was noted to be non-significant. Overall mean value of leaf area duration (LAD) for all treatment was 348.68 days. Table 5.

Table 5. Effect of irrigation scheduling and seeding rates on Leaf area duration (days) in wheat.

Treatments	Seeding rate			
Irrigation level	**SR_1 (100 kg/ ha)**	**SR_2 (125 kg/ha)**	**SR_3 (150 kg ha)**	**Mean**
I_1	395.24	399.47	404.92	**399.88 a**
I_2	366.11	373.14	331.12	**356.79 b**
I_3	300.96	311.65	334.27	**315.63 c**
I_4	309.82	322.58	334.94	**322.45 c**
Mean	**343.03**	**351.71**	**351.31**	

Means not sharing a common letter differ significantly at $p \leq 0.05$ LSD Value for Irrigation = 24.79

Total dry matter production (g/m^2)

Total dry matter production was significantly affected by different irrigation frequencies. The data given in (Table 6) exhibited that total dry matter (TDM) production was remarkably increased by increasing amount of irrigation water. The final dry matter accumulation gradually enhanced with time upto maturity.

Table 6. Effect of irrigation scheduling and seeding rates on Total dry matter production (g m^{-2}) in wheat .

Treatments	Seeding rate			
Irrigation level	**SR_1 (100 kg ha/)**	**SR_2 (125 kg /ha)**	**SR_3 (150 kg/ ha)**	**Mean**
I_1	1609.74	1640.32	1629.51	**1626.52 a**
I_2	855.81	900.53	884.91	**880.42 c**
I_3	970.42	1025.09	1140.37	**1045.29 b**
I_4	1089.92	1157.39	1215.46	**1154.26 b**
Mean	**1131.47 b**	**1180.83 ab**	**1217.56 a**	

Means not sharing a common letter differ significantly at $p \leq 0.05$ LSD Value for irrigation = 112.45, LSD Value for seed rate = 83.52

In relation to irrigation treatments, the highest value of TDM (1626.5 g /m^2) was noted in I1 when irrigation water was applied at sensitive growth stages i.e. tillering, booting, anthesis and grain formation stages. Moisture stress imposed at grain development stage (I_4) and at anthesis stage (I_3) reduced dry matter production by 29.03 and 35.73 percent, respectively than treatment I_1.However, drought stress at tillering stage accumulated the lowest value of TDM (880.4 g/ m$^{2)}$. Wajid (17), Noorka *et al*. (12), Noorka *et al.* (13) also reported that irrigation regimes considerably increased the TDM production of crop during same environmental regions. Data explained that effect of different seeding rates was significant regarding TDM in the study. Maximum TDM (1217.6 g m^{-2}) was recorded in plots that seeded with 150 kg ha^{-1} while minimum TDM (1131.5 g m^{-2}) was found in case of treatment SR_1 where 100 kg per hectare seed rate was applied. The interactive response of irrigation levels and seeding rates during the season was recorded to be statistically non-significant. Overall mean value for all treatment was remained 1176.6 g m^{-2} in the study.

Net assimilation rate (g/m^2/day)

The average net assimilation rate (NAR) of a crop indicates the net photosynthetic production per unit leaf area duration (LAD) (6), but interaction was non-significant (Table 7).

Table 7. Effect of irrigation scheduling and seeding rates on Net assimilation rate (m^{-2} day^{-1}) in wheat.

Treatments	Seeding rate			
Irrigation level	**SR_1 (100 kg /ha)**	**SR_2 (125 kg /ha)**	**SR_3 (150 kg/ ha)**	**Mean**
I_1	4.09	4.11	4.02	4,07 a
I_2	2.34	2.41	2.72	2.49 c
I_3	3.25	3.29	3.43	3.32 b
I_4	3.53	3.59	3.62	3.58 b
Mean	3.30	3.35	3.45	

Means not sharing a common letter differ significantly at $p \leq 0.05$, LSD Value for Irrigation = 0.45

In case of irrigation treatment, net assimilation rate (NAR) was significantly increased (4.07 g/m^2/day) with increasing irrigation frequencies (no water stress applied) at all critical growth stages. The average value of NAR (3.58 g/m^2/day) was observed in case of irrigation regimes I_4 where drought stress imposed at grain formation stage. The lowest quantity of NAR (2.49 g/m^2/day) was observed in I_2 that was 38.82 percent less than I_1 treatment and 18.43 percent less than I_3, respectively, when moisture stress was applied at tillering growth stage. Other factors which highly affected NAR are; water, temperature, light, carbon dioxide, leaf age, mineral nutrients, chlorophyll content and genotype. The analysis of variance regarding seeding rates depicted that NAR was non- significantly influenced by application of various seeding rates. Maximum NAR (3.45 g/m^2/day) was measured at higher seeding rate (150 kg/ha$^{)}$ which is statistically at par with seeding density of 125 kg (3.35 g/m^2/day). However, lower planting rate of 100 kg gave minimum amount of net assimilation rate (3.30 g).The average NAR for the treatment was remained 3.37 g/m^2/day. The interactive response between studied factors was observed to be non-significant. Similar results were reported by Hussain *et al.* 2012.

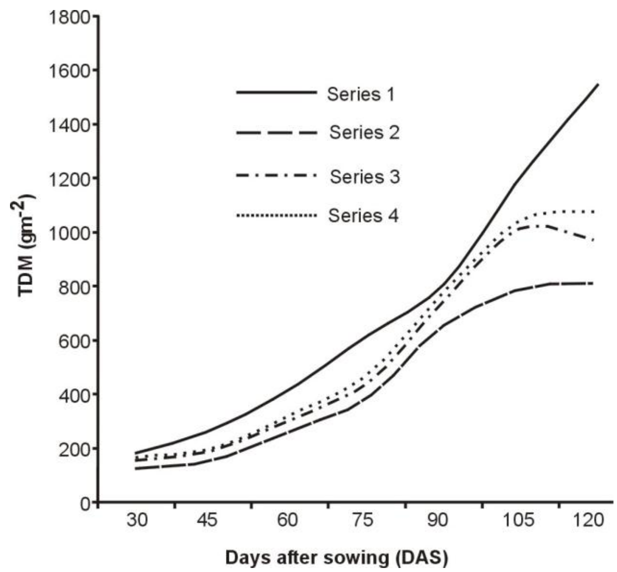

Fig. 1. Effect of irrigation scheduling on TDM (g/m^2) production in wheat.

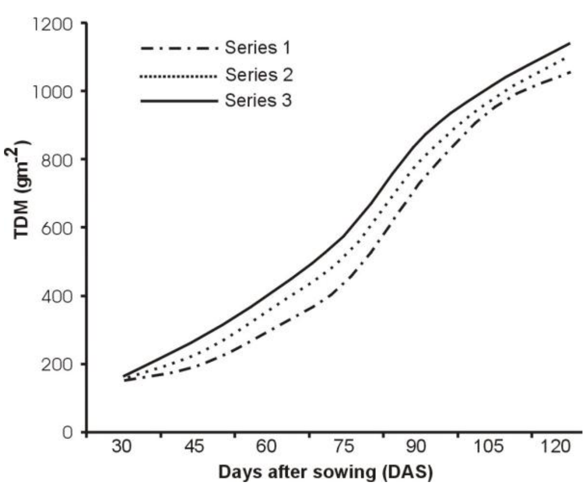

Fig. 2. Effect of seeding rates on TDM (g/m^2) production in wheat.

CONCLUSION

The study concluded that crop irrigated at critical growth stages i.e. tillering booting anthesis and grain formation stages performed better with application of seeding at @ 150 kg per hectare for growth, crop production and net assimilation rate.

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Safdar Aziz	**:**	**Conducted the research**
Tasneem Khaliq	**:**	**Corrected and improved the manuscript**
Amjed Ali	**:**	**Helped in data collection**
Ijaz Rasool Noorka	**:**	**Helped in the preparation of manuscript and submission**