International Journal of Agriculture Innovations and Research
Volume 6, Issue 1, ISSN (Online) 2319-1473
Manuscript Processing Details (dd/mm/yyyy) :
Received: 09/06/2017 | Accepted on : 15/06/2017 | Published : 17/07/2017

Effect of Terminal Drought Stress on Morpho-Physiological and Yield Potential Traits of Bread Wheat Genotypes

Anil Poudel[1*], Surya Kant Ghimire[1], Bishnu Raj Ojha[1], Barun Dev Acharya[1] and Dhruba Bahadur Thapa[2]
[1]Agriculture and Forestry University, Rampur, Chitwan.
[2]Agribotany Division, Wheat Breeding Unit, NARC, Kathmandu, Nepal.
*Corresponding author email id: anil.poudel5@gmail.com

Abstract – **The field experiment was conducted with 50 bread genotypes at the research farm of Agriculture and Forestry University, Rampur from December 2014 to April 2015 to identify the morpho-physiological traits, yield and yield potential traits in advanced lines and commercial varieties of bread wheat associated with drought tolerance and to screen drought tolerant wheat genotypes The experiment was carried out in alpha lattice design with two replications under irrigated and drought conditions. The results of combined analysis of variance and mean comparisons showed significant differences for all the genotypes in both conditions. Mean values of all the morpho-physiological, yield and yield potential traits showed decrease in drought tress condition in comparison to the irrigated condition because of the response to drought stress. In drought stress condition, the genotype WK 2507 produced the highest yield with 2.4 ton/ha while the genotype WK 2513 produced the lowest yield with 0.095ton/ha. In irrigated condition, the genotype WK 2437 produced the highest yield with 2.94 ton/ha while the genotype WK 2523 produced the least yield with 0.272 ton/ha. However, genotypes WK 2525, WK 2507, Munal#1, WK 2437 were superior for grain yield in both drought and irrigated conditions. The genotypes WK 2507, WK 2503, WK 2524 were promising lines for drought condition. Correlation studies showed the significant positive correlation between grain yield with thousand grain weight under drought condition while it days to heading, and flag leaf senescence in drought and irrigated conditions.**

Keywords – **Drought, Genotypes, Wheat, Yield.**

I. Introduction

Wheat is a temperate cereal with an optimum temperature regime of 15-18°c during the grain filling stage. With an average 0.06ºC/year, a rise in temperature from 1975 to 2006 by 1.8ºC has been recorded in the country [1]. Change in climate due to greenhouse effect have made the earth warmer and have changed the precipitation pattern resulting the incidence of floods or drought globally [2]. Moreover, the drought problem under wheat growing season is more pronounced in Nepal and severe dry periods are increasing, concomitantly irrigation is one of the production constraints of Nepalese agriculture especially during rain off seasons.

Drought stress is characterized by reduction of water content, diminished leaf water potential and turgor loss, closure of stomata and decrease in cell enlargement and growth. Severe water stress may result in the arrest of photosynthesis, disturbance of metabolism and finally the death of plant [3]. Water stress inhibits cell enlargement more than cell division. It reduces plant growth by affecting various physiological and biochemical processes, such as photosynthesis, respiration, translocation, ion uptake, carbohydrates, nutrient metabolism and growth promoters (Jaleel *et al.,* 2008). In wheat, there are several genes which are responsible for drought stress tolerance and produce different types of enzymes and proteins for instance, late embryogenesis abundant (lea), responsive to abscisic acid (Rab), rubisco, helicase, proline, glutathione-S-transferase (GST), and carbohydrates during drought stress.

It is the need of time to develop the varieties, which have drought tolerant potential to increase area under cultivation and yield of wheat crop in Nepal. The present study will be aimed to screen out drought tolerant varieties of wheat with high yield potential, through understanding of physio-morphological traits in response to drought stress. Ultimately, it helps in the mitigation process of climate change effects, water scarcity, and food security which improves the livelihood of the farmer, living in poor marginal rainfed land of Nepal.

II. Materials and Methods

The research was conducted at Agronomy research farm under Agriculture and Forestry University, Rampur, Chitwan. Geographically, Rampur is in the Terai belt at 27º 37' N Latitude and 84º 25' E Longitude at an altitude of 256 m asl. This place has a humid sub-tropical climate where summers are hot and winters are cold with total annual rainfall reported as 1582.6 mm. All the meteorological information like temperature, rainfall, relative humidity was recorded in National Maize Research program, Rampur, Chitwan. The rice- wheat cropping system of the field is selected as research field. There was be wheat crop during December 2014 to June 2015 and rice is planted until the next season, i.e. Nov. 2015.

Composite soil samples were taken from the field at different depth (0-30) cm for soil analysis. A set of 50 wheat genotypes were taken from Agriculture Botany Division, Nepal Agriculture Research Council (NARC), Khumaltar, Nepal. They consist of forty-five Wheat Khumal (WK) lines, one Nepal line (NL), one commercial variety and three promising wheat genotypes developed for rain fed conditions of Nepal hills. WK 1204 was used as the standard check variety. The experiment was conducted in Alpha Lattice design, at moisture stress environments and with irrigations as normal condition. Each set of experiment

International Journal of Agriculture Innovations and Research
Volume 6, Issue 1, ISSN (Online) 2319-1473

was replicated two times in both environments. Irrigated plots were supplied with irrigation as per recommended and needed dose in critical stages. Drought experiment will be conducted within the plastic tunnel. To avoid the drought plot from moisture (rain as well as dews), the drought plot was covered with a removable plastic sheet which was removed in the morning and put on the evening. The size of the plot will be $3m^2$(3 m x 1m). The sowing was done in December, 2014 at the seed rate of 150 kg/ha. Every genotype was sown in a 25cm row space consisting of 3 rows per treatment. Genotypes with the replicates will be randomized. The manure was used at the rate of 15ton/ha and the individual plots will be fertilized with recommended dose of 120:60:60 kg NPK/ha. All the phosphorus, potash and half dose of nitrogen were applied before sowing. The remaining dose of nitrogen was applied in two split doses. The field was made weed-free whenever seen. The traits taken for data observations were days to booting, days to heading, days to anthesis, days to flag leaf senescence, days to maturity, flag leaf area, plant height, canopy temperature, SPAD reading, relative water content, thousand grain weight, number of grains per spike, grain weight per spike, biomass yield and grain yield.

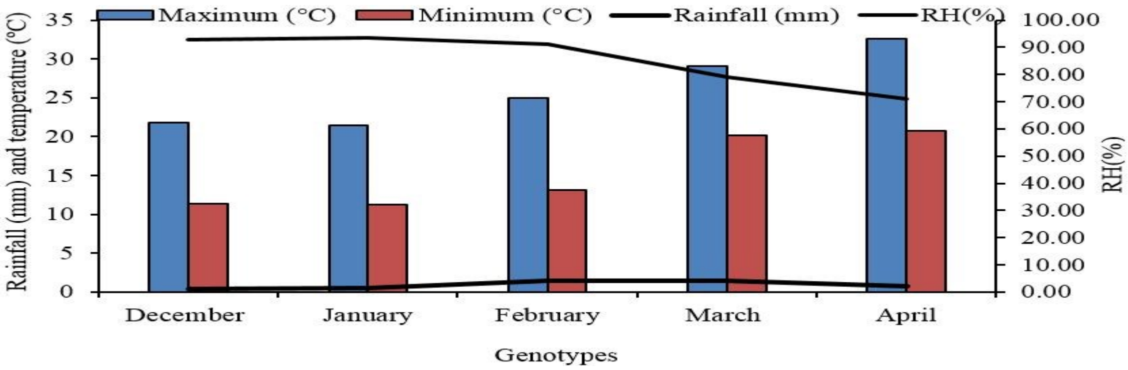

Fig. 1. The monthly average maximum and minimum temperature, relative humidity and rainfall over the experimental period in Rampur, Chitwan, 2014/2015

Data entry and processing was carried out using Microsoft Office Excel 2007. Analysis of variance of all parameters and calculation of means was done by using R.3.2.1 software package for alpha lattice design. Correlation coefficient between various morpho-physiological, secondary and yield attributing traits was done by SPSS 16 software package. Multivariate analysis (UPGMA clustering and PCA) was done by using MINITAB 15 software package. Graphs and tables were constructed by using MS Office Excel program.

Table I. List of the genotypes used for the experiment

Entry No.	Genotypes	Entry No.	Genotypes
1	WK 2208	26	WK 2480
2	WK 2248	27	WK 2485
3	WK 2272	28	WK 2486
4	WK 2278	29	WK 2494
5	WK 2257	30	DANPHE
6	WK 2408	31	WK 2495
7	WK 2414	32	WK 2555
8	WK 2352	33	WK 2558
9	WK 2353	34	WK 2562
10	WK 1204	35	WK 2564
11	WK 2355	36	WK 2566
12	WK 2359	37	WK 2503
13	WK 2381	38	WK 2505
14	WK 2388	39	WK 2506
15	WK 2540	40	MUNAL#1
16	WK 2437	41	WK 2507
17	WK 2438	42	WK 2508
18	NL 1223	43	WK 2509
19	WK 2218	44	WK 2510
20	CHYAKHURA#1	45	WK 2511
21	WK 2519	46	WK 2512
22	WK 2525	47	WK 2513
23	WK 2546	48	WK 2514
24	WK 2550	49	WK 2515
25	WK 2551	50	WK 1481

III. Results

A. Phenological Traits

A.1. Days to Heading and Flag Leaf Senescence

There was highly significant ($P<0.001$) difference in days to heading for the genotypes and blocks in drought and irrigated environments respectively as shown by the ANOVA in Table III. The mean number of days to heading to heading for drought and irrigated condition was almost similar 74.56 days and 75.33 days respectively. In drought condition WK 2355 heading was earliest with the mean of 63 days and WK 2513 heading was the last in 115 days. Similarly, in irrigated condition WK 2495 heading was the earliest with the mean of 65 days and WK 2513 heading was last in 110 days. In drought condition, WK 1204 headed with the mean of 73 days while it was headed almost similar with mean of 73 days in irrigated condition.

There was highly significant difference ($P<0.001$) for the genotypes and at ($P<0.05$) for the environment in days to flag leaf senescence as shown by the ANOVA in Table III. Mean number for days to flag leaf senescence for drought and irrigated condition were 112 days and 113 days respectively. In drought condition, WK 2353 senesced earliest in 101 days where as WK 2513 was senesced last in 138 days. Similarly, in irrigated condition the genotype WK 2505 senesced the earliest in 100days and WK 2513 senesced last in 136 days. WK 1204 senesced with the mean of 109 days in drought condition while it senescence with the mean of 114 days in irrigated condition. Mean days to heading and flag leaf senescence is under drought and irrigated conditions is shown in Table IV and V.

B. Secondary Traits

B.1. Area Under SPAD Retrieve Curve (AUSRC)

There was highly significant difference at (P≤0.001) for the genotypes and environment in area under SPAD retrieve curve (AUSRC) as shown by the ANOVA in Table 3. Mean area under SPAD retrieve curve in drought and irrigated condition was 451.4 and 499 respectively as presented in Table IV and V. In drought condition, WK 2513 had the lowest area under SPAD curve with 261.03 and WK 2480 had the highest area under SPAD curve with 617.4. Similarly, in irrigated condition WK 2513 had the lowest AUSRC with value 207.46 and WK had the highest AUSRC with value 704WK 1204 had mean AUSRC with 435 in drought condition while it was 501 in irrigated condition.

B.2. Flag Leaf Relative Water Content (RWC)

There was highly significant (P≤0.001) difference in flag leaf relative water content for the genotypes and environment in both the conditions as shown by the ANOVA in Table III. The mean relative water content of wheat genotypes in drought condition was 0.86 and for irrigated condition it was 0.97 as shown in Table 4 and 5. WK 2566 had the highest RWC with 1.24 and WK 2516 had the lowest RWC with 0.63 in drought condition. Similarly, highest RWC of WK 2514 with 1.42 and lowest RWC of WK 2512 with 0.57 in irrigated condition. Mean flag leaf relative water content of WK 1204 in drought condition was 0.85 in drought condition while it was 0.89 in irrigated condition. Genotypes WK 2514, WK 2566, WK 2381 showed higher mean relative water content while WK 2218, WK 2495, WK 2513, WK 2512 showed lower relative water in comparison to WK 1204 in both the conditions. Mean flag leaf relative water content of all the genotypes under drought and irrigated treatments is shown in Table IV and V.

C. Yield and Yield Potential Traits

C.1. Plant Height

There was highly significant (P≤0.001) difference for the genotypes and environment in plant height as shown by the ANOVA in Table 3. The mean plant height of wheat genotypes in drought and irrigated condition were 98.5 cm and 103.8 cm respectively as shown in the Appendix 9 and 10. In drought condition, WK 1481 had the highest plant height with 126 cm and whereas WK 2540 had the lowest plant height with 77.25 cm. Similarly, in irrigated condition WK 1481 had the highest plant 140.5 cm and WK 2513 had the lowest plant height 77.15cm respectively. In drought condition, WK 1204 had mean plant height of 86.45cm while it was 94.7cm in irrigated condition. Genotypes WK 1481, WK 2546 showed greater plant height whereas WK 2540, WK 2508, WK 2438 showed lower plant height in both the condition. The mean plant height of all genotypes under and drought irrigated conditions is presented in Table IV and V.

C.2. Thousand Grain Weight and Grain Yield

There was highly significant (P≤0.001) difference in thousand grain weight for the different wheat genotypes as shown by the ANOVA in Table III. Genotype by interaction showed that thousand grain weight was also highly significant (P<0.01) in drought and irrigated environments. The mean thousand grain weight of wheat genotypes under irrigated and drought conditions were 40 gm. For irrigated condition, WK 2513 the least thousand grain weight of 12.8 gm and the highest was for WK 2515, WK 2414 and WK 1481 with thousand grain weight of 60.3 gm, 59.2 gm and 55 gm respectively. Similarly, in drought condition, WK 2546 had the lowest thousand grain weight of 12.2 gm and WK 2510 had the highest thousand grain weight with 49.5 gm. WK 1204 had thousand grain weights of 40 gm in drought condition while it had 34.73 gm in irrigated condition.

There was highly significant difference at (P≤0.001) in grain yield for the genotypes and significant (P≤0.01) difference in grain yield at environment and replication respectively as shown by the ANOVA in Table III. There is also significant difference at (P≤0.05) for the interaction between the genotypes and environment for grain yield. Mean grain yield of wheat genotypes for irrigated and drought conditions were 1.38 ton/ha and 1.57 ton/ha respectively as presented in the Table IV and V. In drought condition, highest grain yield was found in WK 2507 with 2.40 ton/ha which is followed by WK 2502 with 2.11 ton/ha respectively and the lowest grain yield was obtained from WK 2513 with 0.095 ton/ha. Similarly, in irrigated condition the grain yield was highest for WK 2437 with 2.94 ton/ha and the lowest yield was for WK 2513 with 0.272 ton/ha respectively. WK 1204 had grain yield of 1.87 ton/ha in drought condition while it had 2.19 ton/ha in irrigated condition.

Genotypes WK 2507, WK 2503, WK 2352, Munal#1, WK 2525, WK 2486, WK 2558 were superior for grain yield while WK 2513, WK 2505, WK 2546, WK 2562, WK 2511, WK 2414, WK 2248 were inferior for grain yield in drought condition. WK 2437, WK 2525, WK 2506, WK 2381, WK 2515, Munal#1 were superior genotypes for grain yield whereas WK 2513, WK 2388, WK 2257, WK 2485, WK 2546, WK 2494, WK 2278, WK 2564, WK 2480 were inferior genotypes for grain yield in irrigated condition. The mean grain yield of genotypes in both the conditions is presented in the Figure 2. The mean thousand grain weight and grain yield under drought and irrigated conditions is shown in Table IV and V.

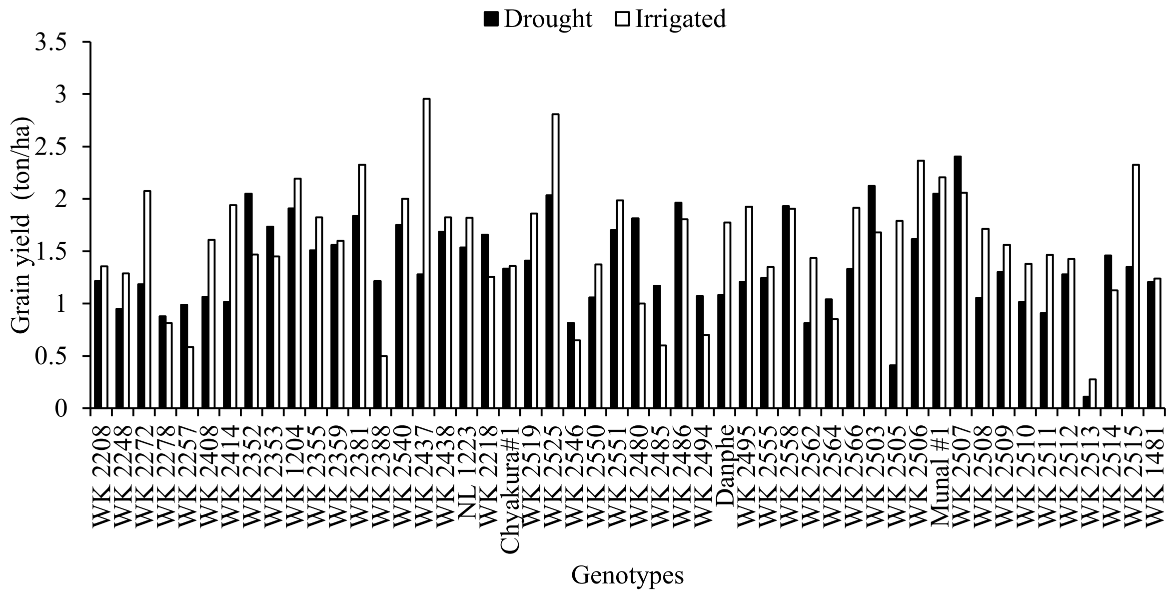

Fig. 2. Comparison between wheat genotypes for grain yield under drought and irrigated conditions at AFU, Rampur (2014/15)

Table III. Combined mean square analysis of variance of different morpho-physiological traits of 50 bread wheat genotypes under drought and irrigated conditions at AFU, Rampur (2014/2015)

Traits	Mean Sum Square Genotype	Mean Sum Square Envt	Mean Sum Square G× E
a. Phenological traits			
• Days to heading	185.37**	29.64	12.71
• Days to flag leaf senescence	131.36***	48.02*	11.91
• Days to maturity	135.08***	6.48	14.23
b. Secondary traits			
• Area under SPAD retrieve curve	19032**	69544**	10033
• Relative water content	0.0585***	0.5875***	0.0071
c. Yield and yield potential traits			
• Plant height	262.274***	1421.2***	398.7
• Leaf area	707***	3658***	
• Thousand kernel weight	147.16***	9.03	60.29***
• Grain yield	0.7814***	1.916***	0.2961*

Table IV.Average values for different morpho-physiological, yield and yield potential traits in drought condition at AFU, Rampur Chitwan (2014/2015)

Entry	DH	DFLS	AUSRC	RWC	PH	TGW	GY
WK 2208	73.01384	112.4558	450.9311	0.7998458	118.16437	37.7276	1.2601166
WK 2248	74.51384	110.9558	504.2061	0.8662675	113.36437	46.6826	0.9951166
WK 2272	71.44309	111.904	452.7946	0.739909	90.35936	44.6484	1.178251
WK 2278	76.43232	113.4161	425.7407	0.8098147	116.54073	40.56109	0.8484738
WK 2257	74.02	112.4923	449.4146	0.9076886	84.22857	41.72205	1.0388147
WK 2408	86.93232	112.4161	446.0557	0.8211851	87.69073	39.25109	1.0334738
WK 2414	73.98308	110.6402	504.0323	1.0796844	100.92211	47.41444	0.9928115
WK 2352	74.94309	111.7958	373.8268	0.8311144	104.1664	43.33349	2.0497226
WK 2353	66.94463	**101.404**	418.439	0.8194097	95.88214	40.64808	1.7504395
WK 1204	**72.99385**	**108.5**	**463.8025**	**0.826146**	**86.43986**	**39.96498**	**1.86664**
WK 2355	**63.01538**	105.064	331.2283	0.8914053	87.93012	35.17218	1.5708335
WK 2359	69.50461	110.3796	364.3736	0.8734156	110.91553	44.45238	1.5478888
WK 2381	73.00461	110.9878	532.2414	1.048537	92.55849	39.19729	1.8164171
WK 2388	90.55383	136.5122	**617.3612**	0.7947699	112.17288	12.7876	1.1952153
WK 2540	69.94309	106.7958	354.6918	0.7798996	**77.0664**	36.21849	1.7497226
WK 2437	69.99385	110	518.3775	0.915183	90.33986	42.02498	1.23664

International Journal of Agriculture Innovations and Research
Volume 6, Issue 1, ISSN (Online) 2319-1473

Entry	DH	DFLS	AUSRC	RWC	PH	TGW	GY
WK 2438	70.94309	109.904	520.9446	0.8430655	84.20936	44.9434	1.678251
NL 1223	70.00461	110.9878	463.5064	0.7945616	99.95849	40.59729	1.5164171
WK 2218	68.5646	102.8918	328.8722	0.7408222	105.49855	39.05001	1.6714641
Chyakura #1	75.57075	112.4283	495.9908	0.9946157	93.56275	44.09946	1.3501621
WK 2519	73.97693	111.7119	525.3566	0.7773902	92.10087	38.53489	1.3776418
WK 2525	75.50461	111.3796	356.2986	0.7854822	84.41553	38.71738	2.0228888
WK 2546	76.0646	115.5	415.38	0.8983606	110.09151	**12.22491**	0.8199924
WK 2550	68.51538	110.064	538.0333	0.8774072	97.58012	44.80218	1.1208335
WK 2551	70.50615	108.4878	417.1208	0.8498035	109.73128	40.70197	1.7036056
WK 2480	69.50308	112.0762	403.8601	0.8277151	95.38871	38.21019	1.8288678
WK 2485	74.07075	110.9283	296.8458	0.8394032	110.56275	32.13946	1.1851621
WK 2486	79.02	107.4923	420.1396	0.9297284	102.42857	41.74705	2.0138147
WK 2494	81.50615	114.4878	392.5458	0.8317263	101.93128	33.81197	1.0736056
Danphe	79.56614	113.5	530.3794	0.8650548	101.2643	43.52459	1.1121809
WK 2495	63.5646	103.3918	361.3522	0.7547017	105.74855	40.98001	1.2164641
WK 2555	73.97693	114.2119	587.7616	0.9847334	110.50087	41.63989	1.2126418
WK 2558	72.44924	112.3323	494.3603	0.9333253	105.0806	47.62295	1.9334207
WK 2562	74.51384	112.564	540.9139	0.7791728	107.65733	47.6025	0.853645
WK 2564	71.44463	115.904	464.359	0.966044	104.18214	47.12808	1.0554395
WK 2566	78.97847	113.7119	526.321	**1.239121**	91.97365	40.79457	1.3198303
WK 2503	70.97847	110.7119	350.161	0.7558447	102.87365	43.60957	2.1148303
WK 2505	72.01077	102.9161	443.0671	0.9572497	93.92973	32.68184	0.4015869
WK 2506	72.50308	111.5762	545.6651	0.7811316	96.68871	41.71019	1.6288678
Munal #1	74.55383	111.5122	420.6262	0.7920264	95.07288	41.9776	2.0302153
WK 2507	69.44924	113.3323	473.6853	0.900409	92.4306	38.78795	**2.408421**
WK 2508	71.01384	103.564	454.5539	0.856434	81.10733	32.7325	1.093645
WK 2509	73.96616	108.7241	397.9428	0.7187923	102.23224	49.07258	1.2428646
WK 2510	79.06614	117	546.0944	0.8560168	89.8143	**49.51459**	1.0421809
WK 2511	77.51077	118.4161	476.4171	0.9022619	86.12973	40.01684	0.9015869
WK 2512	75.96616	118.7241	499.9528	**0.625635**	97.23224	49.17758	1.2228646
WK 2513	**115.0646**	**138**	**261.025**	0.7833512	89.49151	14.94991	**0.114992**
WK 2514	75.98308	120.1402	527.7973	1.134495	95.17211	47.46444	2.1078115
WK 2515	76.47693	114.1037	437.4888	0.8427331	94.35791	42.22498	1.3241134
WK 1481	73.97693	111.6037	445.6138	0.859089	**125.8579**	47.12498	1.1791134
Grand Mean	**74.56**	**112.2**	**451.359**	**0.86164**	**98.5**	**40.0345**	**1.3802**

DTH=Days to heading, DTA=Days to anthesis, DFLS=Days to flag leaf senescence, DM=Days to maturity, PHT=Plant height, LA= Leaf Area, GY=grain yield, RWC= Relative water content, AUSRC= Area under SPAD retrieve curve, TKW= Thousand grain weight

Table V. Average values for different morpho-physiological, yield and yield potential traits in irrigated condition at AFU, Rampur Chitwan (2014/2015)

Entry	DH	DFLS	AUSRC	PH	RWC	TGW	GY
WK 2208	73.95141	115.6317	584.0274	114.79029	0.9507488	24.37859	1.3386261
WK 2248	72.45141	114.6317	580.6524	117.49029	1.0361401	36.50859	1.2736261
WK 2272	74.08907	112.2865	515.4143	93.60791	0.8106254	35.07126	2.0913739
WK 2278	75.10527	117.7278	521.5486	110.04589	0.951482	32.84482	0.8351304
WK 2257	74.54859	113.4208	528.2815	95.40754	1.0564223	40.03025	0.5912042
WK 2408	77.60527	124.7278	555.8186	110.94589	0.8259155	24.68482	1.6301304
WK 2414	68.4838	113.766	556.1759	98.61554	1.0414971	59.22447	1.9404009
WK 2352	78.02429	116.0819	483.3159	121.70687	0.8986053	50.05846	1.4806174
WK 2353	68	102.8799	497.9567	106.73336	0.8824	38.53035	1.4762878
WK 1204	**72.52429**	**113.6637**	**477.1161**	**95.46434**	**0.873889**	**34.7298**	**2.186796**
WK 2355	70.92712	103.4297	362.5383	88.51678	1.0139498	33.67548	1.8242964
WK 2359	68.94332	111.5178	465.8083	108.52532	0.9568279	39.73344	1.5822829

Entry	DH	DFLS	AUSRC	PH	RWC	TGW	GY
WK 2381	73.0081	111.7224	498.4968	98.52636	1.4120742	39.79124	2.3130394
WK 2388	104.55668	123.5	368.7732	102.13444	0.9663282	19.68035	0.5016458
WK 2540	71.02429	108.5819	449.1059	98.90687	0.9244376	33.71846	2.0106174
WK 2437	72.52429	110.1637	477.0411	104.66434	0.9699903	36.0598	**2.946796**
WK 2438	72.58907	110.2865	595.6893	99.45791	0.9529357	37.49626	1.8413739
NL 1223	71.5081	113.7224	461.2068	108.82636	0.9047138	36.44624	1.8080394
WK 2218	69.47571	111.3541	516.8705	113.99542	0.7682764	36.509	1.2471329
Chyakura#1	76.07288	113.6432	471.1895	97.18767	1.2016131	40.57565	1.3747109
WK 2519	74.45141	111.6815	547.4502	94.62433	0.8957512	47.39061	1.8435793
WK 2525	73.94332	114.5178	438.2483	89.22532	0.8987694	45.18344	**2.792283**
WK 2546	77.04049	118.5587	403.7539	123.79646	1.0878375	47.5168	0.6478893
WK 2550	67.92712	105.4297	574.6033	103.71678	0.9611172	39.25048	1.3742964
WK 2551	72.91902	113.3158	450.4842	114.55181	0.9336308	37.55032	1.9829533
WK 2480	71.53239	112.2776	605.5802	101.12931	0.9252667	34.19995	0.9931391
WK 2485	74.07288	108.6432	435.9045	116.18767	1.0097474	42.81565	0.6147109
WK 2486	76.04859	112.4208	501.3115	96.58254	1.0883213	45.03025	1.8112042
WK 2494	79.91902	115.3158	404.2992	109.95181	0.8152304	39.94032	0.6979533
Danphe	77.95141	115.6521	574.5113	94.82191	0.9367775	48.42088	1.7828032
WK 2495	**64.97571**	102.8541	468.3205	107.59542	0.7563301	35.809	1.9171329
WK 2555	73.95141	110.6815	519.5252	120.42433	1.2801808	49.93561	1.3335793
WK 2558	72.12146	114.371	528.1699	102.89912	1.0709401	50.22512	1.9381955
WK 2562	75.5162	113.8363	**703.9458**	110.24133	0.8326291	36.86139	1.4243826
WK 2564	74	117.8799	491.6167	116.73336	1.0768093	42.00535	0.8762878
WK 2566	77.86234	119.2749	562.7677	91.99978	1.2766157	51.3047	1.9084932
WK 2503	71.36234	108.2749	468.3677	100.24978	0.8480832	53.1497	1.6734932
WK 2505	75.04049	**100.3069**	420.3674	120.11757	1.1077085	37.74509	1.794861
WK 2506	75.03239	112.2776	533.5302	92.12931	0.9437115	37.65995	2.3581391
Munal #1	76.55668	109.5	502.2882	96.73444	0.8482595	36.97535	2.2066458
WK 2507	76.62146	111.871	526.5849	103.44912	1.0404258	45.82512	2.0931955
WK 2508	73.0162	102.8363	514.8508	84.24133	1.0192319	26.90139	1.7043826
WK 2509	71.46761	108.1228	476.5346	93.51231	0.7496	48.20417	1.5473358
WK 2510	79.95141	117.1521	519.4613	95.02191	0.8908138	52.37088	1.3878032
WK 2511	81.04049	115.8069	463.9924	99.91757	1.0440558	47.00509	1.469861
WK 2512	77.46761	117.6228	466.5446	109.01231	**0.568379**	41.25917	1.4123358
WK 2513	**110.0405**	**135.5587**	**207.4639**	**77.14646**	0.7594229	**12.7968**	**0.272889**
WK 2514	79.4838	118.266	519.2509	101.16554	**1.422334**	44.63947	1.1254009
WK 2515	76.38663	117.9769	580.8068	98.37329	0.9674234	**60.28281**	2.3028229
WK 1481	73.38663	113.9769	565.9568	**140.4733**	1.0476168	54.96781	1.2178229
Grand mean	**75.33**	**113.18**	**498.8704**	**103.8315**	**0.970038**	**40.4594**	**1.576**

DTH=Days to heading, DFLS=Days to flag leaf senescence, DM=Days to maturity, PHT=Plant height, LA= Leaf Area, GY=grain yield, RWC= Relative water content, AUSRC= Area under SPAD retrieve curve, TGW= Thousand grain weight

D. Correlation Studies

D.1. Correlation Studies under Drought Condition

Correlation studies of the different morpho-physiological, secondary and yield and yield potential traits in drought condition are presented in Table VI. Days to heading showed highly significant positive correlation with days to flag leaf senescence (0.81**) and days to maturity (0.81**) While it showed highly significant negative correlation with grain yield (-0.441**) and thousand grain weights (-0.45**). Days to flag leaf senescence showed highly significant and positive correlation with days to maturity (0.99**) However, it showed negative correlation with grain yield (-0.30*). Days to maturity was negatively correlated with number of thousand kernel weight (0.45*). Grain yield showed highly significant positive correlation thousand grain weight (0.38**).

Table VI. Pearson correlation of different morpho-physiological traits under drought condition at AFU, Rampur, Chitwan Nepal, 2014/15

	DTH	DFLS	DM	GY	AUSRC	TGW
DTH	1	.810**	.809**	-.441**	-0.072	-.451**
DFLS		1	.989**	-.296*	0.151	-.325*
GY				1	0.044	.379**
AUSRC					1	0.128
TGW						1

DTH = Days to heading, DFLS= Days to flag leaf senescence, DM = Days to maturity, GY= Grain yield, AUSRC = Area under SPAD retrieve curve, TGW= Thousand grain weight

D.2. Correlation Studies under Irrigated Condition

Correlation studies of the different morpho-physiological traits, secondary traits, yield and yield potential traits under irrigated condition are presented in Table VII. Days to heading showed highly significant positive correlation with days to flag leaf senescence (0.71**) and days to maturity (0.730**) while it showed highly significant negative correlation with grain yield (-0.44**) and significant negative correlation with thousand grain weight (-0.33*). Days to flag leaf senescence showed highly significant positive correlation with days to maturity (0.998**), spike length (0.36**) but it was negatively correlated with grain yield (-0.37**). Days to maturity showed highly significant negative correlation with grain yield (-0.38**). Plant height was found to be significant and negatively correlated with grain yield (-0.304*). Similarly, AUSRC was significant and positively correlated with thousand grain weight (0.333*).

Table VII. Pearson correlation of different morpho-physiological traits under irrigated condition at AFU, Rampur, Chitwan Nepal, 2014/15

	DTH	DFLS	DM	GY	AUSRC	TGW
DTH	1	.705**	.730**	-.439**	-0.21	-.330*
DTA		.694**	.718**	-.456**	-0.222	-.358*
DFLS		1	.998**	-.365**	0.022	-0.123
DM			1	-.375**	0.01	-0.132
PHT				-.304*	0.179	0.234
GY				1	0.166	0.228
AUSRC					1	.333*
TKW						1

DTH= Days to heading, DFLS= Days to flag leaf senescence, DM= Days to maturity, GY= Grain yield, AUSRC= Area under SPAD retrieve curve, TGW= Thousand grain weight

E. Multivariate Analysis

E.1. UPGMA Clustering

E.1.1. Cluster Analysis under Drought Condition

The dendrogram of flag leaf senescence, leaf area, plant height, biomass yield, grain yield, relative water content, AUSRC under drought condition are presented in figure 15. Distance among different cluster centroids are presented in the Table 8. The dendrogram is classified into two major groups and six clusters. Group A consists of five clusters and Group B has only one cluster. Cluster was obtained based on similarity percentage and related characters. The Group A consists of five clusters and 49 genotypes. Cluster I was found to be the largest cluster and divided into three quadrants. Right quadrant consists of .10 genotypes i.e. WK 2208, WK 2272, WK 2564, WK 2507, WK 2257, Chyakhura#1, WK 2408, WK 2508, NL1223, Mid quadrant consists of 8 genotypes i.e. WK 2278, WK 2551, WK 2509, WK 2546, WK 2480, WK 2505, WK 2511. Left quadrant consist of 4 genotypes i.e. WK 2353, WK 1204, WK 2515, WK 1481. It has been observed that the genotypes in this cluster have early flag leaf senescence, small leaf area, plant height, low in biomass yield and grain yield, low in relative water content, AUSRC, and thousand grain weight. Cluster II was the second largest cluster and consists of 30% of the genotypes. Left quadrant consist of 5 genotypes viz. WK 2248, WK 2550, WK 2566, WK 2506, WK 2514. Middle quadrant consists of 7 genotypes i.e. WK 2414, WK 2519, WK 2562, WK 2381, Danphe, Munal#1, WK 2438. Genotypes WK 2558, WK 2510, WK 2512 were grouped into the right quadrant of second cluster. It has been found that the genotypes with higher value of traits like days to flag leaf senescence, flag leaf area, biomass yield, grain yield, relative water content, AUSRC, and thousand grain weight grouped into this cluster. Similarly, cluster III consists of 10 genotypes (WK 2352, WK 2355, WK 2540, WK 2218, WK 2359, WK 2494, WK 2495, WK 2503, WK 2525, WK 2485) which represents 20% of the total genotypes. The genotypes with highest value of grain yield and thousand grain weight were grouped into this cluster. Cluster IV consists of two genotypes (WK 2388, WK 2555), which contributes 4% of the total genotypes. The genotypes in this cluster have lowest values of leaf area, grain yield and thousand grain weight. Cluster V consists of WK 2513. In this group, the genotype showed lowest values for plant height, grain yield, relative water content, AUSRC, thousand grain weight with late in flag leaf senescence.

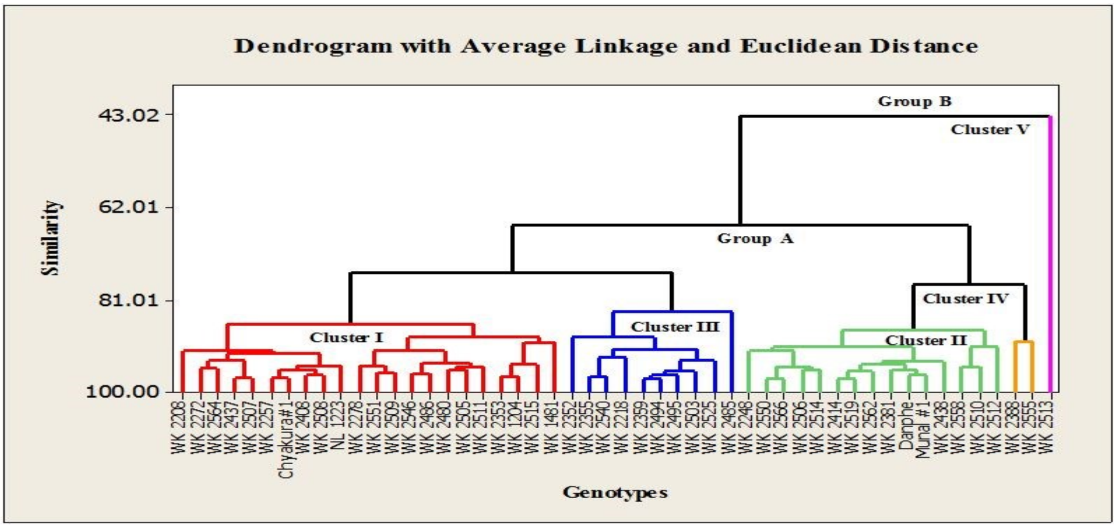

Fig. 3. UPGMA (unweighted pair group method arithmetic average) Clustering of 50 genotypes based on different morpho-physiological traits, yield and yield potential under drought condition at AFU, Rampur (2014/2015)

Table VIII. Distances between cluster centroids under drought condition at AFU, Rampur, Chitwan (2014/2015)

	Cluster1	Cluster2	Cluster3	Cluster4	Cluster5
Cluster1	0.000	95.719	95.968	180.393	212.274
Cluster2		0.000	191.489	87.233	306.790
Cluster3			0.000	275.978	120.408
Cluster4				0.000	388.923
Cluster5					0.000

IV. Discussion

A. Major Drought Responsive Traits

A.1. Days to Flag Leaf Senescence

The increased in the flag leaf senescence in stressed condition in comparison to non-stressed have been found in the literature. It has been reported that the “stayed green” or delayed senescence plays an important role in grain development during stress conditions which allow the plants to retain their green leaves for a prolonged grain filling period. Terminal drought stress stimulates the senescence of the wheat plant which may increase nutrient remobilization from the stem to developing grains and this may compensate for senesce induced losses in grain yield [4]. Stay green genotypes might contribute to higher yield and enhance drought tolerance if normal photosynthesis duration is prolonged and there is high intrinsic chlorophyll concentration so the delayed senescence is considered to desirable trait in cereal breeding.

A.2. Days to Maturity

The highly significant (P<0.001) difference for days to maturity in genotypes suggested the genotypes were fall into different maturity group. It had been confirmed with the findings of others [5]-[6]. The interaction between genotype and environment was non-significant and it showed no variability across environment. The decrease in maturity days under stressed is controlled by the lower of nutrients in the plants with decreased chlorophyll in leaves due to the lack of nitrogen needed for the assimilation. The loss of the chloroplast integrity in the leaf causes the early senescence in drought that ultimately leads plant to mature early.

A.3. Area Under SPAD Retrieve Curve (AUSRC)

[7] found the similar reports of decrease in chlorophyll content in drought stress conditions. AUSRC is decreased in the drought stress treatment because the drought stress decrease the total the total chlorophyll content is found to reduce under water stress conditions. Drought stress inhibits the photosynthesis of plants by causing changes in chlorophyll content, by affecting chlorophyll pigments and by damaging the photosynthetic apparatus. The chlorophyll content in flag leaves reflects the photosynthetic activity and yield potential of wheat genotypes. It has been found that decrease in chlorophyll content faster in drought sensitive than in drought tolerant genotypes. It has been reported that high chlorophyll capacity of wheat genotypes under drought condition could be identified by selecting the genotypes with high chlorophyll capacity. SPAD meter reading measures the total chlorophyll content in the leaves that could be used as a screening tool for selecting the genotypes under drought condition. The results also agree with the explanation given by [8].

A.4. Plant Height

Highly significant (P≤0.01) differences among the genotypes for plant height showing variation in plant height agreed with the findings of [9]- [10]. [10] reported the similar findings of significant difference in environment and non-significant difference of genotype and interaction in plant height for wheat genotypes. The decrease in plant height of all genotypes in drought condition in comparison to irrigated condition may be due to decrease in relative turgidity and dehydration of protoplasm which is associated with a loss of and reduced expansion of cell and cell division. The reduction in plant height under water stress condition could be attributed to decline in cell enlargement and more leaf senescence [11]. These results are similar with findings of [12] who had observed significant reduction in plant height under drought stress condition.

A.5. Thousand Grain Weight (TGW)

Highly significant difference (P<0.001) in thousand grain weight for genotypes indicates the variability among genotypes revealed with findings of [13]. Decrease in thousand grain weight under drought stress condition was reported by [14]. The decrease in thousand grain weight may be due distributed nutrient uptake efficiency and photosynthetic translocation within the plant that produced shriveled grains due to hastened maturity [15]. This is possible due to the shortage of moisture which forces plant to complete its grain formation in relatively lesser time. Grain weight is a function of grain length and width. [16], [17] reported the critical period of grain weight determination which starts shortly before anthesis and continues throughout the grain filling duration determines the final grain size in wheat. Thus, drought stress during grain-filling period reduces grain weight significantly.

A.6. Grain Yield

[18] reported highly significant ($P \leq 0.001$) differences in genotypes showing variation for grain yield that confirms with our findings. [19] reported the similar findings. Genotype by environment interaction was significant ($P \leq 0.05$) for grain yield showing variation among genotypes across different moisture regime confirmed with the reports of [20]- [21]. Decrease in grain yield under drought condition was reported by many researches [22]- [23]- [24]. Grain yield was greater in irrigated condition than in drought environment as a consequence of more spikes per square meter, heavier grains, and a longer plant cycle. The as significant reduction in grain yield due to post anthesis water stress may result from a reduction of production of photo-assmilates (source limitation), power of the sink to absorb photo-assimilates and the grain filling duration. [9] reported the severe reduction in grain yield with 40% reduction at three irrigation stage to 98% in the post anthesis indicates that the sensitivity of grain yield to drought stress depends upon the severity of the stress and the stage in which the drought condition was imposed.

B. Correlations Studies

The negative and significant correlation between days to heading and grain yield in drought condition were similar with the reports *[14]*. These findings were also in the agreement with findings of several workers [25]- [26]. Negative association between days to maturity with grain yield also confirmed with the findings of [26]- [27]. Likewise, significant positive correlation of grain yield with thousand grain weight in drought treatment were in support with the findings of [10]) and other researchers such as [28]. In drought stress condition, some of the genotypes compensate grain yield loss through transfer of photo-assimilates to the developing grains which may cause increase in number of grains per spike along with the increased grain weight per spike and thousand grain weight which finally results in increment of grain yield. Significant negative correlation of plant height with grain yield in irrigated condition agreed with the findings of [19]**.** The reason is that the increase in plant height would result in reduction of grain yield because of mobilization of carbohydrates towards the reproductive organ for seed formation rather to vegetative organ. Highly significant positive correlation of thousand grains weight and grain weight per spike in irrigated treatment agreed with the findings of [10]. [29] reported that the chlorophyll content was positively correlated with biomass yield in drought condition.

V. Conclusion

Wheat (*Triticum aestivum*) is the third most important cereal crop of Nepal after rice and maize. Drought stress is the major problem in wheat production in many parts of the world including Nepal. It is one of the most common environmental stresses which affect the plant production through the alteration in plant metabolism and gene expression. It is the major challenge to agriculture scientists and plant breeder's despite in the present scenario for the wheat production despite of many decades of research. It is the major constraint to the wheat production in many developing countries of the world and occasional causes of loss of agricultural production in many developed ones. Drought stress may occur at any time during the wheat growing season i.e. early or late however severe yield reduction occurs after anthesis. The amount and distribution of rainfall during the wheat growing season influence influenced the variability in yield from year to year and from location to location. It is necessary to improve productivity of wheat under rainfed and dry conditions in Nepal through breeding of drought tolerant cultivars with high yield to solve the problems of food security.

The mean values of all phenological traits, secondary traits, yield and yield potential traits in drought condition were less than in irrigated condition. Genotypes were significantly different for all phenolgoical traits in irrigated and drought treatments. Days to flag leaf senescence showed significant difference for environment and genotypes. Mean number of days to flag leaf senescence was 112.2 days and 113.8 days in drought and irrigated environment respectively. Similarly, the mean days to maturity were 116.97 days and 117.33 days in drought and irrigated treatment respectively. Secondary traits area under SPAD retrieve curve, relative water content and canopy temperature showed significant difference for environment and genotypes. It was observed mean AUSRC of 459 and 493 in drought and irrigated condition respectively. It was observed significant difference in genotypes and environments for yield and yield potential traits. Genotype by environment interaction showed significant difference for grain yield and thousand grains weight. The mean thousand grains weight was 40.03gm in drought condition while it was 40.45 gm in irrigated. Similarly, the mean grain yield was 1.38 ton/ha in drought condition whereas it was 1.57 ton/ha in irrigated condition. In drought stress condition, the genotype WK 2507 produced the higher yield (2.4 ton/ha) followed by genotypes while the genotypes WK 2507 (2.40 ton/ha), WK 2503 (2.11 ton/ha), WK 2514 (2.10 ton/ha), WK 2352 (2.04 ton/ha) and Munal#1 (2.03 ton/ha). In irrigated condition, the genotype WK 2437 produced the higher yield (2.94 ton/ha) followed by WK 2506 (2.35 ton/ha), WK 2381 (2.31 ton/ha) and WK 2515 (2.30 ton/ha).

Correlation studies were performed among different morpho-physiological traits in drought and irrigated conditions. Days to heading also showed highly significant and positive correlation with days to flag leaf senescence in drought and irrigated environments. It was observed highly significant and negative correlation of days to heading with grain yield and thousand grains weight in both the environments. Days to flag leaf senescence showed highly significant and positive correlation with days to maturity while it was significant and negative correlated with grain yield in drought and irrigated conditions. There was significant and negative correlation of plant height with grain yield under irrigated condition. Grain yield showed highly significant positive correlation with thousand grains weight and significant positive correlation with number of grains per spike in drought condition whereas it showed highly showed highly significant and positive correlation with thousand grains weight in irrigated condition. UPGMA clustering of genotypes were done to identify the genotypes with similar traits which can be useful for selecting parents in breeding programs. The greater the distance between parents for individual components of yield, the greater the progeny variance. The genotypes belonged to respective cluster could be used in crop improvement program for respective character. This study can help plant breeders to increase the genetic diversity by selecting materials from divergent parentage for crosses, which can reduce the vulnerability to diseases and climate changes.

VI. Recommendations for Further Research

Genotypes WK 2507, WK 2503, WK 2352, Munal#1, WK 2525, WK 2486, WK 2558 were identified as drought tolerant and high yielding genotypes under our drought stress condition. It is recommended for further wheat breeding research in rainfed and drought conditions of Terai and inner-Terai of Nepal. WK 2513, WK 2505, WK 2546, WK 2562, WK 2511, WK 2414, WK 2248 were drought sensitive genotypes and they are not recommended for cultivation under drought and rainfed conditions. WK 2437 and WK 2525 were identified as high yielding genotypes for grain yield under irrigated condition and it can be recommended for further wheat breeding research in irrigated conditions of Terai and inner Terai. However, genotypes WK 2525, WK 2507, Munal#1 and WK 2437 were superior genotypes for grain yield in both drought and irrigated conditions. Genotypes WK 2353, WK 2218, WK 2355, WK 2495, WK 2505 were early for phenological traits like days to booting, heading, flag leaf senescence and maturity. Hence it can be recommended for terminal drought stress condition in Terai and inner-Terai as early varieties.

Acknowledgments

Authors thank to the Directorate of Research (DOR) for providing the financial support and Nepal Agriculture Research Council (NARC), Agri-botany Division for providing seed materials to conduct this research.

References

[1] Regmi, H. R. "Effect of unusual weather on cereal crop production and household food security." *Journal of Agriculture and Environment* 8 (2007): 20-29.

[2] Wassmann, Reiner, et al. "Climate change affecting rice production: the physiological and agronomic basis for possible adaptation strategies." *Advances in agronomy* 101 (2009): 59-122.

[3] Sankar, B., et al. "Relative efficacy of water use in five varieties of Abelmoschusesculentus (L.) Moench. under water-limited conditions." *Colloids and Surfaces B: Biointerfaces* 62.1 (2008): 125-129.

[4] Yang, Jianchang, et al. "Hormonal changes in the grains of rice subjected to water stress during grain filling." *Plant Physiology* 127.1 (2001): 315-323.

[5] Ullah, Rafi, et al. "Heritability for heading, maturity, plant height, spike length and tillers production in winter wheat (Triticumaestivum L.)." *Pak. J. Pl. Sci* 13.1 (2007): 67-73.

[6] Ahmad, Munir, et al. "Physio-morphic response of wheat genotypes under rainfed conditions." *Pak. J. Bot* 38.5 (2006): 1697-1702.

[7] Kuroda, Molonaka, Tetsuo Oaiawa, and Hiroshi Imagawa. "Changes in chloroplast peroxidase activities in relation to chlorophyll loss in barley leaf segments." *Physiologiaplanta--rum* 80.4 (1990): 555-560.

[8] Del Blanco, I. A., et al. "Physiological performance of synthetic hexaploid wheat-derived populations." *Crop Science* 40.5 (2000): 1257-1263.

[9] Kazmi, Rashid Hussain, M. Qayyum Khan, and M. KaleemAbbasi. "Effect of water stress on the performance of wheat grown under controlled conditions at Rawalakot, Azad Jammu and Kashmir [Pakistan]." *Sarhad Journal of Agriculture (Pakistan)* (2003).

[10] Nouri-Ganbalani, Alireza, Gadir Nouri-Ganbalani, and Davoud Hassanpanah. "Effects of drought stress condition on the yield and yield components of advanced wheat genotypes in Ardabil, Iran." *Journal of Food, Agriculture & Environment* 7.3&4 (2009): 228-234.

[11] Jaleel, C. Abdul, et al. "Pseudomonas fluorescens enhances biomass yield and ajmalicine production in Catharanthusroseus under water deficit stress." *Colloids and Surfaces B: Biointerfaces* 60.1 (2007): 7-11.

[12] Bayoumi, T. Y., Manal H. Eid, and E. M. Metwali. "Application of physiological and biochemical indices as a screening technique for drought tolerance in wheat genotypes." *African Journal of Biotechnology* 7.14 (2008).

[13] Naser, H. M., et al. "Effects of time and frequency of irrigation on yield of wheat." *Thai Journal of Agricultural Science (Thailand)* (1999).

[14] Kilic, Hasan, and Tacettin Yagbasanlar. "The effect of drought stress on grain yield, yield components and some quality traits of durum wheat (Triticumturgidum ssp. durum) cultivars." *Notulae Botanicae Horti Agrobotanici Cluj-Napoca* 38.1 (2010): 164.

[15] Jenner, C. F. "Starch synthesis in the kernel of wheat under high temperature conditions." *Functional Plant Biology* 21.6 (1994): 791-806.

[16] Sinclair, T. R., and P. D. Jamieson. "Grain number, wheat yield, and bottling beer: an analysis." *Field Crops Research* 98.1 (2006): 60-67.

[17] Ji, Xuemei, et al. "Importance of pre-anthesis anther sink strength for maintenance of grain number during reproductive stage water stress in wheat." *Plant, Cell & Environment* 33.6 (2010): 926-942.

[18] Asif, M., et al. "Stability of wheat genotypes for grain yield under diverse rainfed ecologies of Pakistan." *Asian J. Plant Sci* 2.4 (2003): 400-402.

[19] Khamssi, Nahid Niari, and Abdollah Najaphy. "Agro-morphological and phenological attributes under irrigated and rain-fed conditions in bread wheat genotypes." *African Journal of Agricultural Research* 7.1 (2012): 51-57.

[20] Dabiry, Shokouh, et al. "Drought Tolerance of Advanced Bread Wheat Genotypes Based on Different Drought Tolerance Criteria." *Biological Forum*. Vol. 7. No. 2. Research Trend, 2015.

[21] Mahmodi, Nasrin, Anita Yaghotipoor, and Eztollah Farshadfar. "AMMI stability value and simultaneous estimation of yield and

yield stability in bread wheat ('Triticumaestivum'l.)." *Australian Journal of Crop Science* 5.13 (2011): 1837.

[22] Gooding, M. J., et al. "Effects of restricted water availability and increased temperature on the grain filling, drying and quality of winter wheat." *Journal of Cereal Science* 37.3 (2003): 295-309.

[23] Ozturk, A., and F. Aydin. "Effect of water stress at various growth stages on some quality characteristics of winter wheat." *Journal of Agronomy and Crop Science* 190.2 (2004): 93-99.

[24] Wardlaw, Ian F. "Interaction between drought and chronic high temperature during kernel filling in wheat in a controlled environment." *Annals of botany*90.4 (2002): 469-476.

[25] Munir, M., M. A. Chowdhry, and T. A. Malik. "Correlation studies among yield and its components in bread wheat under drought conditions." *International Journal of Agriculture and Biology (Pakistan)* (2007).

[26] Subhani, Ghulam Mahboob, and Muhammad Aslam Chowdhry. "Correlation and path coefficient analysis in bread wheat under drought stress and normal conditions." *Pakistan Journal of Biological Sciences* 3.1 (2000): 72-77.

[27] Singh, K. N., S. P. Singh, and G. S. Singh. "Relationship of physiological attributes with yield components in bread wheat under rainfed condition." *Agric. Sci. Digest* 15.1-2 (1995): 11-14.

[28] Ashraf, M. Yasin, and A. Hafeez Khan. "Effect of drought stress on wheat plant in early stage." *Pakistan Journal of Agricultural Research (Pakistan)* (1993).

[29] Zaharieva, M., et al. "Drought and Heat Responses in the Wild Wheat Relative Roth." *Crop Science* 41.4 (2001): 1321-1329.

AUTHORS' PROFILES

Anil POUDEL

Author was born in Bharatpur-8, Parasnagar, Chitwan, Nepal in 10th October 1987. He completed his undergraduate degree in Agriculture from Institute of Agriculture and Animal Sciences under Tribhuvan University, Nepal in 2010. He has graduated as Master of Science in Agriculture from Agriculture and Forestry University with Genetics and Plant Breeding as major. His research interests are mainly focused on resistance breeding and genetics. He was involved in many plant breeding research activities conducted by the department of Genetics and Plant Breeding during his undergraduate and postgraduate studies. He had worked as INSTRUCTOR AND PROGRAM CO-ORDINATOR under Council of Technical Education and Vocational Training (CTEVT) after the completion of his graduation (2011-2013). Currently he is involved in research works and papers.

Dr. Dhruba Bahadur THAPA

Dr, Thapa was born in 11th September 1961 in Kathmandu, Nepal. He was graduated in Agriculture from Institute of Agriculture and Animal Science, under Tribhuvan University in 1980. He studied Master of Science in Agriculture from Patrice Lummumba Peoples, Friendship University, Moscow Former USSR in 1990. Similarly, he obtained Doctor in Philosophy in Plant Breeding in 1993 from Russian Peoples' Friendship University, Moscow Russia. He is mainly focused on wheat breeding and research activities in Nepal. He has joined Nepal Agriculture Research Council (NARC) as a SCIENTIST(S-1) from 1994. Currently, he is working as a SENIOR SCIENTIST (S-4) in Agribotany Division, Wheat Breeding Unit, Nepal Agriculture Research Council. He has published his many research articles in different national and international journals. Dr. Thapa is a Life member of Society of Agriculture Scientist since 1999. He is an Advisor, Founder and Life member of Democratic Agriculturists Association Nepal since 2013. He has obtained different national and international awards and fellowships.