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Original article

Evaluation of morphological and physiological traits of wheat (*Triticum aestivum* L.) cultivars under Flooding stress conditions and its relationship with grain yield

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Abstract

Flooding stress is one of the most important stresses related to autumn plants especially in the northern parts of the country. The most cost-effective and reliable way to reduce the effects of environmental stresses on crops is to choose a resistant cultivar. Therefore, this experiment was conducted to investigate Flooding stress tolerance in wheat genotypes using some morphological and physiological characteristics and its relationship with grain yield. This experiment was conducted as a factorial experiment in a completely randomized design with 3 replications and two factors: 1) Flooding stress (non-flooding and 15 days flooding) and 2) cultivar (20 cultivars) at Gorgan University of Agricultural Sciences and Natural Resources in 2016-17. Done. Based on the results of this experiment, the highest grain yield was observed in N-80-19, N-87-20 and N-91-14 under non-stress conditions, which were 1.95 and 1.88 g pl^{-1}, respectively. Under flooding conditions, the highest grain yield was obtained in N-80-19 (1.02 g pl^{-1}) and Kohdasht (0.96 g pl^{-1}) cultivars. The results showed that leaf area, leaf dry weight, chlorophyll a and b, root volume and dry weight, carotenoid and SPAD were affected by the destructive effects of Flooding stress and were significantly reduced under non-stress conditions. Leaf area had the highest correlation (0.89) with grain yield, after leaf area, chlorophyll a and SPAD had the highest correlation with grain yield. Based on the results of this experiment, it can be concluded that leaf area, photosynthetic pigments, SPAD number and root volume in wheat genotypes were highly correlated under water stress conditions with wheat grain yield, Therefore, genotypes with more photosynthetic leaf area at vegetative stage can be identified as resistant genotypes to Flooding stress. Carotenoid and SPAD were affected by the destructive effects of Flooding stress and were significantly reduced under non-stress conditions. Leaf area had the highest correlation (0.89) with grain yield, after leaf area, chlorophyll a and SPAD had the highest correlation with grain yield. Based on the results of this experiment, it can be concluded that leaf area, photosynthetic pigments, SPAD number and root volume in wheat genotypes were highly correlated under water stress conditions with wheat grain yield, Therefore, genotypes with more photosynthetic leaf area at vegetative stage can be identified as resistant genotypes to flooding stress.

Keywords: Chlorophyll, Chlorophyll meter number, Cultivar, Leaf area, Root dry weight

Table 1. Characteristics of wheat cultivars cultivated in Golestan province from 1968-2015

No. of cultivar	Name of cultivar	Year of Introduced	No. of cultivar	Name of cultivar	Year of Introduced
1	Inia	1968	11	Morvarid	2009
2	Khazar1	1973	12	Gonbad	2011
3	Naz	1978	13	Karim	2011
4	Falat	1990	14	N-87-20	2013
5	Atrak	1995	15	N-90-7	2014
6	Zagros	1995	16	N-91-8	2015
7	Tajan	1995	17	N-91-9	2015
8	Kohdasht	2000	18	N-91-10	2015
9	N-80-19	2005	19	N-91-14	2015
10	Line17	2006	20	N-91-17	2015

Adapted from Golestan Agricultural Research Center

Table 2. Characteristics of the studied soil

Characteristic	value
pH	7.1
Electrical conductivity	0.55 (dsm^{-1})
Total Nitrogen	0.016 (%)
Saturation percentage	6.2 (S.P)
Available phosphorus	14.2 (ppm)
Available potassium	173.2 (ppm)

Table 3. Analysis of variance flooding stress and cultivar on some morphological, physiological traits and wheat seed yield

Source of variance	Df	Plant height	Root dry weight	Root mass	Stem dry weight	Leaf area	Leaf dry weight
Flooding stress (F)	1	12.53^{ns}	0.033**	0.053**	0.002^{ns}	2440.0**	3.19**
Cultivar (C)	19	84.70**	0.005**	0.002**	0.011**	104.4**	0.06**
F × C	19	1.38^{ns}	0.007*	0.006*	0.0002^{ns}	12.6**	0.02**
Error	80	7.69	0.004	0.0003	0.001	6.1	0.001
CV(%)	-	*9.20*	*21.0*	*10.58*	*9.03*	*11.3*	*7.9*

Table 3. Continued

Source of variance	Df	Seed yield	Catalase	Carotenoid	Chlorophyll b	Chlorophyll a	SPAD
Flooding stress (F)	1	27.09**	12060**	384.9**	1794.4**	967.9**	8964.5**
Cultivar (C)	19	0.08**	41496**	3.1**	22.1**	21.3**	46.8**
F × C	19	0.02**	25442**	0.77*	3.4*	7.8**	6.5**
Error	80	0.01	733	0.39	1.8	2.7	2.5
CV(%)	-	*8.4*	*5.5*	*11.4*	*10.8*	*9.8*	*7.5*

n.s, * and ** Non significant and significant at levels probability 5 and 1%, respectively.

Table 4. Mean comparison of flooding stress and cultivar on physiological, morphological traits and grain yield of wheat cultivars

Flooding stress	Cultivar	Leaf area	Leaf dry weight	Root mass	Root dry weight
		cm^2 $plant^{-1}$	g $plant^{-1}$	cm^3 $plant^{-1}$	g $plant^{-1}$
0 days	**Morvarid**	30.72^{c}	0.73^{ed}	0.31^{bcd}	0.22^{bc}
	Gonbad	25.94^{d}	0.64^{f}	0.28^{edc}	0.20^{cbd}
	N-87-20	23.56^{ed}	0.53^{g}	0.29^{cde}	0.19^{ced}
	Naz	22.54^{edf}	0.48^{gh}	0.27^{ef}	0.18^{ed}
	Inia	22.87^{edf}	0.49^{gh}	0.28^{ef}	0.18^{ed}
	Kazar 1	23.56^{ed}	0.50^{hg}	0.28^{ed}	0.19^{cbde}
	Atrak	30.39^{c}	0.49^{gh}	0.32^{ab}	0.22^{b}
	Zagros	25.94^{d}	0.49^{gh}	0.29^{cde}	0.18^{ed}
	Falat	19.80^{f}	0.44^{h}	0.25^{f}	0.14^{f}
	N-80-19	35.84^{a}	1.06^{a}	0.34^{a}	0.26^{a}
	Tajan	25.94^{d}	0.60^{f}	0.30^{bcde}	0.20^{bcd}
	Line 17	21.85^{ef}	0.53^{g}	0.28^{e}	0.17^{ed}
	Kohdasht	34.48^{ab}	0.94^{b}	0.34^{a}	0.25^{ab}
	Karim	24.58^{ed}	0.72^{ed}	0.29^{cde}	0.20^{cbd}
	N-90-7	31.06^{bc}	0.83^{c}	0.31^{abc}	0.22^{cbd}
	N-91-8	25.25^{ed}	0.67^{ef}	0.29^{cde}	0.20^{cbd}
	N-91-9	31.39^{bc}	0.74^{d}	0.32^{ab}	0.22^{b}
	N-91-10	22.54^{edf}	0.64^{f}	0.29^{cde}	0.19^{cde}
	N-91-14	25.94^{d}	0.75^{d}	0.28^{cde}	0.21^{bcd}
	N-91-17	23.89^{ed}	0.62^{f}	0.28^{ed}	0.20^{bcd}
15 days	**Morvarid**	19.71^{bcde}	0.37^{ab}	0.27^{abc}	0.20^{abc}
	Gonbad	17.12^{defgh}	0.31^{cde}	0.27^{abc}	0.18^{bcd}
	N-87-20	14.71^{figh}	0.27^{ef}	0.22^{gh}	0.13^{g}
	Naz	13.08^{hi}	0.27^{ef}	0.22^{gh}	0.13^{gf}
	Inia	13.20^{igh}	0.28^{ef}	0.22^{fgh}	0.14^{efg}
	Kazar 1	13.59^{igh}	0.28^{e}	0.23^{efgh}	0.14^{efg}
	Atrak	13.33^{igh}	0.36^{b}	0.24^{defgh}	0.13^{gf}
	Zagros	13.65^{figh}	0.36^{bc}	0.23^{efgh}	0.12^{g}
	Falat	11.82^{i}	0.23^{f}	0.21^{h}	0.10^{g}
	N-80-19	29.43^{a}	0.42^{a}	0.26^{bcde}	0.21^{ab}
	Tajan	16.69^{defgh}	0.30^{e}	0.26^{bcde}	0.18^{bcd}
	Line 17	14.09^{figh}	0.28^{ef}	0.24^{cdefg}	0.16^{edf}
	Kohdasht	23.94^{b}	0.41^{ab}	0.29^{ab}	0.23^{a}
	Karim	17.58^{defg}	0.29^{e}	0.26^{abcd}	0.18^{bcd}
	N-90-7	20.66^{cbd}	0.38^{ab}	0.27^{abc}	0.21^{abc}
	N-91-8	18.09^{cdef}	0.29^{e}	0.26^{bcd}	0.19^{bcd}
	N-91-9	19.87^{bced}	0.36^{bcd}	0.30^{a}	0.18^{bcd}
	N-91-10	15.68^{efghi}	0.27^{ef}	0.27^{abcd}	0.18^{bcd}
	N-91-14	22.25^{cb}	0.30^{ed}	0.25^{cdef}	0.18^{bcd}
	N-91-17	19.22^{ced}	0.28^{ef}	0.26^{bcde}	0.17^{cde}

Means by the same letter in each column are not significantly different according to LSD range tests ($P<0.05$).

Table 4. Continued

Flooding stress	Cultivar	Chlorophyll a	Chlorophyll b	Carotenoid	Catalase	SPAD	Seed yield
		---------- mg.g^{-1} FW ----------			Mmol.min^{-1} FW		g plant^{-1}
0 days	**Morvarid**	20.60^{abc}	16.94^{bcdefg}	7.44^{abcde}	423.07^{abc}	31.02^{bcdef}	1.82^{abc}
	Gonbad	21.35^{abc}	15.53^{cdefg}	7.02^{cde}	367.53^{ef}	27.93^{efg}	1.72^{bedc}
	N-87-20	20.15^{abc}	15.86^{cdefg}	6.64^{cde}	361.07^{ef}	27.17^{g}	1.88^{ab}
	Naz	20.24^{abc}	15.17 ^{defg}	7.38^{abcde}	335.37^{f}	27.03^{g}	1.67^{edc}
	Inia	19.12^{dc}	14.81^{efg}	7.13 ^{bcde}	417.23^{abcd}	28.73^{cdefg}	1.56^{ed}
	Kazar 1	19.05^{dc}	14.68^{g}	7.58^{abcd}	362.83^{ef}	27.67^{g}	1.67^{edc}
	Atrak	19.45^{bc}	17.20^{bcdef}	7.64^{abcd}	411.77^{abcd}	31.22^{bcde}	1.80^{abc}
	Zagros	18.79^{dc}	14.94^{defg}	6.65^{cde}	361.08^{ef}	27.53^{g}	1.58^{ed}
	Falat	16.58^{d}	14.76^{efg}	6.20^{e}	396.59^{abcd}	31.56^{bcd}	1.68^{edc}
	N-80-19	22.39^{a}	20.14^{a}	8.30^{ab}	427.56^{ab}	35.78^{a}	1.95^{a}
	Tajan	20.42^{abc}	17.22^{bcdef}	7.15^{bcde}	386.41^{cde}	29.69^{bcdefg}	1.75^{bcd}
	Line 17	19.07^{dc}	14.67^{g}	7.23^{abcde}	391.02^{bcde}	29.73^{bcdefg}	1.69^{bdec}
	Kohdasht	21.98^{ab}	19.36^{ab}	8.48^{a}	433.46^{a}	35.59^{a}	1.80^{abc}
	Karim	21.04^{abc}	16.96^{bcdefg}	7.06 ^{bcde}	382.86^{de}	28.93^{cdefg}	1.64^{edc}
	N-90-7	19.89^{abc}	17.01^{bcdefg}	7.58^{abcd}	423.00^{abc}	31.98^{bc}	1.80^{abc}
	N-91-8	18.74^{dc}	15.70^{cdefg}	6.98^{cde}	379.93^{de}	28.52^{defg}	1.74^{bdc}
	N-91-9	20.38^{abc}	17.81^{abc}	7.82^{abc}	426.50^{ab}	32.25^{b}	1.54^{e}
	N-91-10	19.02^{dc}	17.25^{bcde}	6.50^{ed}	368.00^{ef}	27.73^{fg}	1.66^{edc}
	N-91-14	19.10^{dc}	15.81^{cdefg}	7.31^{abcde}	393.02^{bcde}	29.49^{cdefg}	1.83^{abc}
	N-91-17	19.48^{bc}	17.40^{bcd}	7.38^{abcde}	385.24^{cde}	28.93^{cdefg}	1.66^{edc}
15 days	**Morvarid**	16.07^{b}	11.28^{ab}	4.34^{cdef}	551.31^{hgi}	14.29^{cd}	0.88^{abcd}
	Gonbad	12.91^{defg}	8.29^{def}	3.46^{ghi}	500.81^{kj}	12.27^{ef}	0.81^{bcdef}
	N-87-20	11.90^{efgh}	5.69^{ghi}	2.26^{jk}	482.69^{kj}	8.27^{i}	0.67^{fg}
	Naz	10.32^{gh}	4.88^{i}	2.03^{k}	370.55l	7.71^{i}	0.58^{gh}
	Inia	10.77^{fgh}	5.92^{ghi}	2.26^{jk}	450.53^{k}	7.81^{i}	0.49^{h}
	Kazar 1	11.57^{fgh}	6.83^{fghi}	3.09^{hi}	489.05^{kj}	10.29^{gh}	0.75^{fde}
	Atrak	16.17^{b}	8.86^{cde}	3.90^{cdefg}	609.32^{ed}	12.72^{edf}	0.70^{fge}
	Zagros	11.57^{fgh}	6.92^{efgh}	2.83^{ij}	504.80^{ijk}	8.98^{hi}	0.48^{h}
	Falat	10.19^{h}	4.98^{hi}	2.19^{jk}	456.52^{k}	8.78^{hi}	0.47^{h}
	N-80-19	19.46^{a}	13.28^{a}	5.46^{a}	973.96^{a}	19.70^{a}	1.02^{a}
	Tajan	13.33^{cdef}	8.20^{def}	3.66^{fgh}	602.48^{edf}	13.48^{ed}	0.85^{bdec}
	Line 17	12.07^{efgh}	7.59^{efg}	3.89^{defg}	522.91^{hji}	10.99^{gf}	0.87^{abcd}
	Kohdasht	19.23^{a}	11.86^{ab}	5.17^{ab}	855.62^{b}	18.50^{a}	0.96^{ab}
	Karim	14.55^{bcde}	10.38^{bc}	4.41^{cde}	621.83^{ed}	13.34^{ed}	0.80^{fdec}
	N-90-7	17.09^{ab}	12.02^{ab}	4.71^{bc}	728.41^{c}	15.67^{cb}	0.93^{abc}
	N-91-8	15.03^{bcd}	8.44^{cdef}	3.72^{efgh}	642.23^{ed}	13.65^{ed}	0.89^{abcd}
	N-91-9	17.22^{ab}	11.78^{ab}	4.58^{bcd}	725.72^{c}	16.21^{b}	0.81^{fbdec}
	N-91-10	12.98^{defg}	8.64^{cdef}	3.69^{fgh}	555.83^{fgh}	12.26^{ef}	0.76^{fde}
	N-91-14	15.85^{bc}	10.02^{bcd}	4.10	649.87^{d}	14.26^{cd}	0.93^{abc}
	N-91-17	14.98^{bcd}	8.67^{cdef}	4.06	599.21^{efg}	13.31^{ed}	0.80^{fdec}

Means by the same letter in each column are not significantly different according to LSD range tests (P<0.05).

Table 5. Mean comparison of flooding stress and cultivar on plant height and dry shoot weight wheat cultivars

Cultivar	Plant height	Dry shoot weight
	cm	g.plant^{-1}
Morvarid	33.3^{ab}	0.406^{bcde}
Gonbad	29.3^{bcdef}	0.379^{cdef}
N-87-20	28.5^{def}	0.350^{fg}
Naz	26.8^{ef}	0.340^{fg}
Inia	26.8^{ef}	0.339^{fg}
Kazar 1	28.6^{cdef}	0.366^{ef}
Atrak	32.9^{abcd}	0.417^{abcd}
Zagros	28.4^{ef}	0.362^{efd}
Falat	21.3^{g}	0.259^{h}
N-80-19	36.9^{a}	0.434^{ab}
Tajan	30.3^{bcde}	0.367^{def}
Line 17	25.4^{fg}	0.315^{g}
Kohdasht	37.3^{a}	0.462^{a}
Karim	29.8^{bcde}	0.376^{cdef}
N-90-7	33.0^{abc}	0.406^{bcde}
N-91-8	29.6^{bcdef}	0.379^{cdef}
N-91-9	33.6^{ab}	0.422^{abc}
N-91-10	28.7^{cdef}	0.364^{efg}
N-91-14	30.4^{bcde}	0.389^{bcdef}
N-91-17	31.0^{bcde}	0.372^{def}

Means by the same letter in each column are not significantly different according to LSD range tests ($P<0.05$).

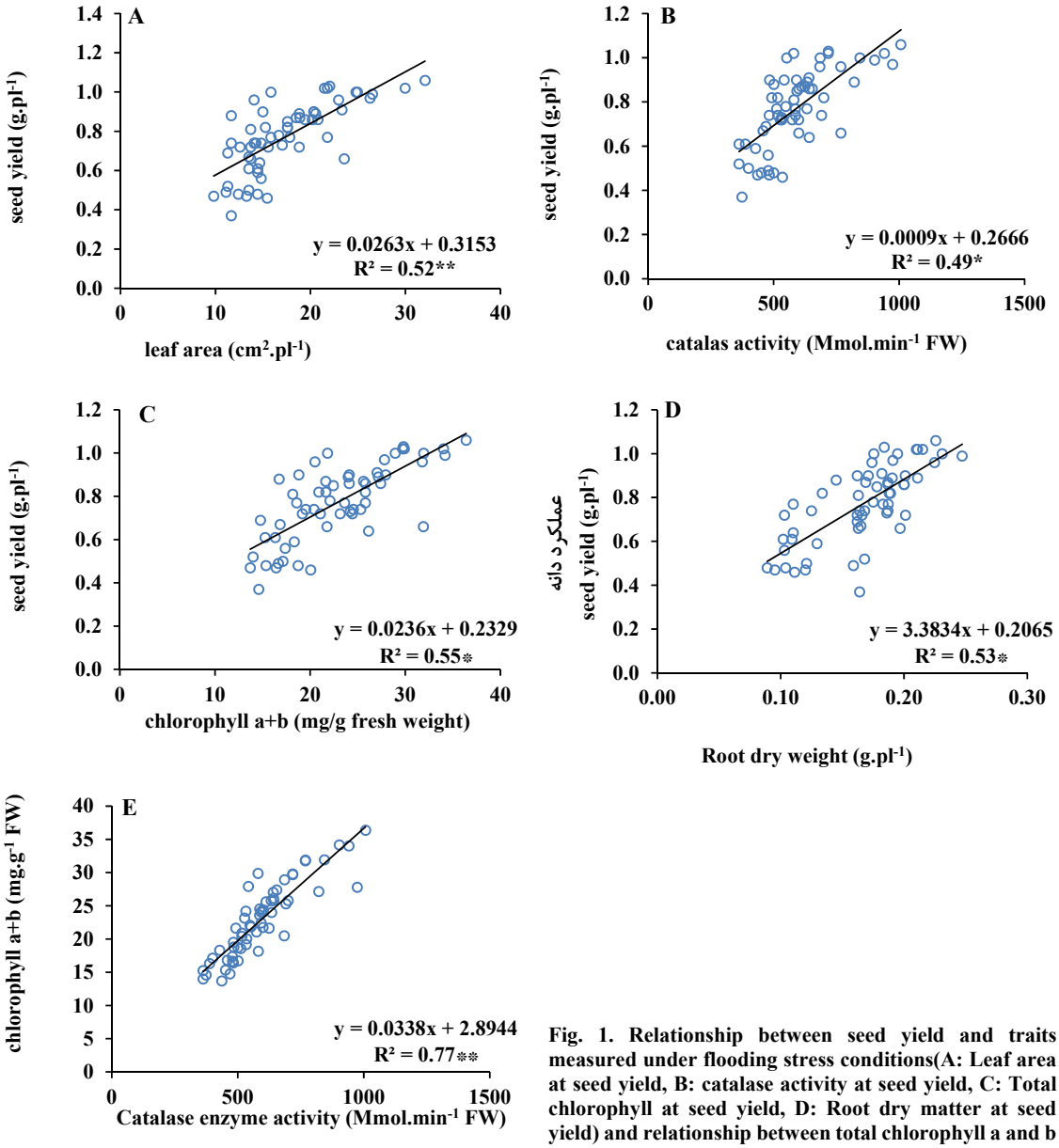

Fig. 1. Relationship between seed yield and traits measured under flooding stress conditions(A: Leaf area at seed yield, B: catalase activity at seed yield, C: Total chlorophyll at seed yield, D: Root dry matter at seed yield) and relationship between total chlorophyll a and b and catalase activity (E)

Table 6. Correlation coefficients between measured traits and wheat seed yield

		1	2	3	4	5	6	7
1	Leaf area	1						
2	Root dry weight	0.68**	1					
3	Root mass	0.59**	0.68**	1				
4	SPAD	0.53**	0.63**	0.69**	1			
5	Chlorophyll a	0.56**	0.55*	0.73**	0.87**	1		
6	Catalase enzyme activity	0.63**	0.74**	0.59**	0.76**	0.69**	1	
7	Seed yield	0.89**	0.71**	0.74**	0.75**	0.88**	0.64**	1

n.s, * and ** Non significant and significant at levels probability 5 and 1%, respectively.

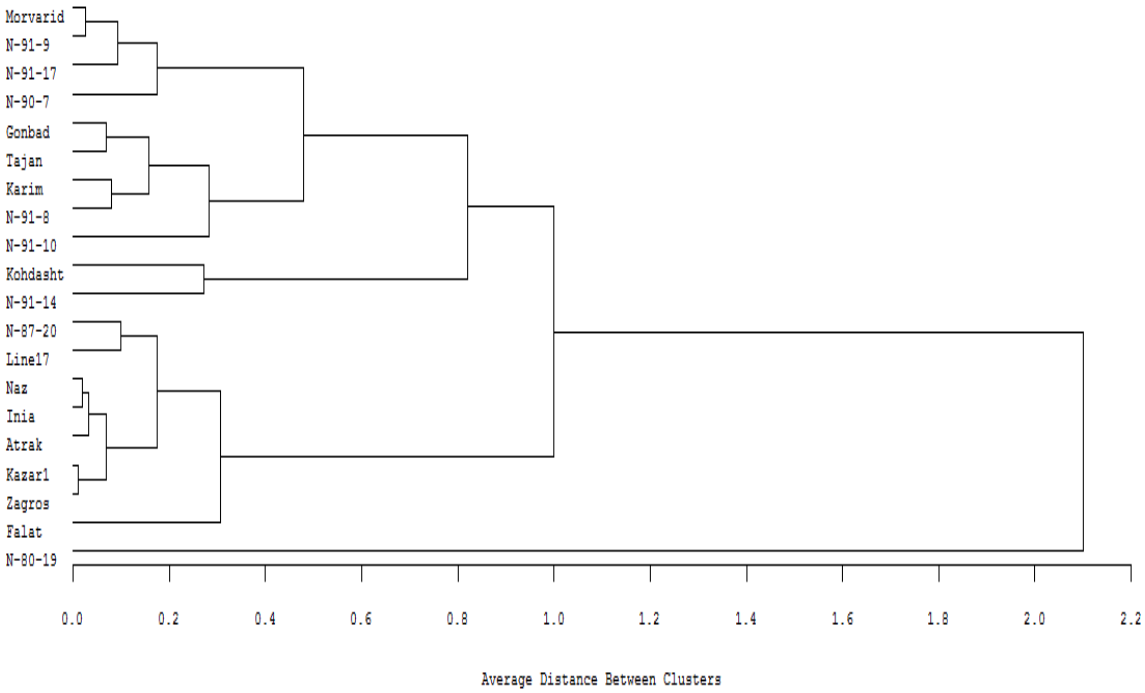

Fig. 2. Cluster analysis of different varieties of wheat leaf area under flooding stress