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Sowing Dates Affected Productivity and Wilting Disease of Bread Wheat on Vertisols in the Highlands of Central Ethiopia

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Abstract: Four sowing dates (10,17, 24, & 31 July) were tested over 12 sites in 2007 & 2008 so as to quantify bread wheat productivity and infection levels of wilting disease called *Gasash*, caused mainly by *Fusarium sp* on black soils. Broad bed and furrows (BBF) made by BBF maker on the first sowing date and manually made BBF on the later sowing dates were used to drain excess soil water. Grain yield significantly ($p<0.05$) increased with delaying sowing dates on *Mererie* soil (relatively heavy black soil) while the response was significantly ($p<0.05$) quadratic for *Bushella* soil (relatively light black soil) at Deneba, Enewarie and Goshebado. At these three locations, count of *Gasash* infected wheat plants per m^2 on both soil types of four sites in 2007 linearly decreased while number of fertile wheat spikes per m^2, which were free from *Gasash*, linearly increased with delaying sowing dates at significant probability level ($p<0.05$). Number of fertile spikes significantly ($p<0.05$) correlated with grain yield. Thus, sowing of bread wheat on 22-31 July for *Mererie* soil; and on 16-26 July at which the soil approaches saturation for *Bushella* soil is advisable on Vertisols at Deneba, Enewarie, Goshebado and similar areas in the highlands of central Ethiopia.

Key words: Sowing dates · Bread wheat · Gasash · Vertisols · Broadbed and furrows · Central Ethiopia

INTRODUCTION

Vertisols are black clay soils which are prone to waterlogging that seriously reduces their productivity. The Ethiopian highland Vertisols, higher than 1500m altitudes above sea level, covers about 7.6 million hectares, of which 35000 hectares of land on the high elevation of Enewarie plateau at 2600m above sea level (asl) is considered as wheat belt that has been supported by relatively efficient traditional drainage method (broad bed and furrows) of smallholder farmers in the highlands of central Ethiopia [1]. Recent field observations by the author in November 2006 revealed that bread wheat covered about 65% of the total cropped Vertisol areas at Enewarie and Deneba. The traditional broad bed and furrows drainage method, which has been in service since the 16 century [2], has accelerated the expansion of wheat production in the highland Vertisols of Enewarie [1] and Deneba areas. However, as opposed to the recommendations, farmers' sowing dates of bread wheat have been late in the highland Vertisols of central Ethiopia in general and in Enewari plateau including Deneba and Goshebado areas in particular. Regardless of the hard push since 1986 [3] to disseminate the broad bed and furrow drainage method made by oxen drawn broad bed maker (BBM) for early sowing recommendation, the adoption rate was disappointing on Vertisols of Ethiopia [4]. Rutherford [5] by quoting the work of Ayalneh (2008) reported that out of 137697 BBMs ready for distribution in Amhara Regional State of Ethiopia, only 20603 (about 15%) were distributed to farmers, while the remaining were left in stores for lack of demand in the year 2008 cropping season.

The most important argument of farmers for not using BBM in Enewarie areas is its association with early sowing that causes yield loss due to waterlogging of Vertisols. As the soil is not saturated at early sowing, it continues to sip in more water and swells, but after saturation it discharges excess water and the soil settles down that effectively reduces the depth of drainage furrows, hampering free movement of drainable excess water I the furrows. Thus early sown wheat, even if it is

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provided with broad bed and furrows, faces waterlogging that reduces yield. Farmers believe that the sowing date and productivity of bread wheat vary according to the soil type and moisture condition of the soil. Using manually made broad bed and furrows, farmers sow wheat relatively earlier (13 to 24 July) when the soil becomes saturated on relatively light Vertisols called *Bushela*, while sow it late in 25 July to 6 August to get saturated and muddy soil condition on relatively heavy Vertisols called *Mererie*. They believe that late sowing on *Mererie* soil makes plants vigorous with deep green leaves and hence minimize nitrogen fertilizer requirement for top-dressing. Whenever early sowing is done on *Mererie* soil, plant growth is depressed with pronounced chlorosis that usually may result in either higher amount of nitrogen fertilizer requirement for top-dressing or total crop failure caused by waterlogging and the associated wilting disease locally called *Gasash*. *Gasash* is a premature drying of wheat plants that result in infertile spikes (spikes with no grain). Visual field observations and wheat plant samples collected by researchers of in 2004 cropping season from failed waterlogged crop fields on Vertisols in North Shewa Administrative Zone of Amhara Regional State, in which Enewarie plateau is included, also partly confirmed the farmers' experience and also identified *Gasash* to be caused by *Fusarium sp* and *Helmintosporium sp* (Asnakech Beyene, Pers. comm.). The other important reason of late sowing practice by farmers is the associated reduction of weed pressure by plowing under as soon as weed emerges after effective rainfall. Research also confirmed that *Polygonum nepalense* and *Phalaris paradoxa* are among early emerging broad leafed and late emerging grassy weeds, respectively, on highland Vertisols of Ethiopia [6] that are choking wheat for waterlogging condition makes hand weeding control very difficult practice. Under such circumstances, farmers rejected the blanket recommendation of early sowing while the soil is moist and friable so as to use BBM for making broad bed and furrows. Therefore, a multi-location experiment was conducted in 2007 and 2008 with the objective of determining the effects of sowing dates on bread wheat productivity and *Gasash* infection levels on Vertisols using manually and BBM made broad bed and furrows in the highlands of central Ethiopia.

MATERIALS AND METHODS

Sites representing relatively heavy Vertisol (*Mererie*) and relatively light Vertisol (*Bushella*) were selected with the participation of farmers in each location. Areas surrounding Deneba (9°46'N & 39°09'E), Enewarie (9°53'N & 39°08'E) and Goshebado (9°44'N & 39°27'E) represent the test locations with the altitude of 2600-2850m asl. Four sowing date treatments (10, 17, 24 and 31 July), with ± 1 day, were tested in 2007 and 2008. The first sowing date (10 July) was done while the soil was moist and oxen drawn broad bed and furrow maker (BBM) was used to make broad beds and furrows (BBF) so as to drain excess soil moisture. Broad beds and furrows were made manually for other sowing dates as the soil was highly saturated and muddy that made impossible to use BBM. The broad bed with 80 cm width is in between two furrows each with 40 cm width. The crop grows on the broad beds while the drainable water leaves the field flowing in furrows. Plot size was 6*15 m^2 without replication per site. Total number of sites in the two years was 12. Bread wheat variety HAR-2501 (Hawi) was used as the test crop. Seed and fertilizer rates were 150 kg ha^{-1} seed and 156/60 kg ha^{-1} of N/P fertilizer, respectively. Diammonium phosphate (DAP) and urea were used as the source of N and P in such a way that all DAP and half of urea was applied at sowing, while the remaining half of urea was applied at tillering stage of wheat just after weeding. Data collection included one composite soil sample (five core samples made one composite) of each experimental site to the depth of 0-30 cm and 30-60 cm for each soil type at each location, rainfall data, yield, number of fertile spikes m^{-2}, number of non-fertile (spikes hit by *Gasash*) spikes m^{-2} after heading, spike length and number of seeds per spike. Analysis of variance and trend analyses using orthogonal contrast were done using Mixed Procedure of SAS software Version 8.1 of 1999-2000, SAS Institute Inc. Cary, NC, USA. Locations, soil types, sowing dates and their interaction were treated as fixed terms in the combined analysis over years, locations and soil types. Year was considered as replication since there was no replication per site for each soil type thus year was treated as random factor. There was no significant interaction of the three locations (Deneba, Enewarie and Goshebado) with soil types and sowing dates, but soil type by sowing date interaction was significant ($p<0.05$). Therefore, separate analysis for each soil type across these three locations was made. Trend analysis was also made accordingly. Pearson correlation was made for grain yield with number of fertile spikes m^{-2}, spike length and number of seeds per spike; the probability of significance was tested using two tailed test.

RESULTS AND DISCUSSION

The combined analysis of sowing dates over the three locations (Deneba, Enewarie and Goshebado) and the two soil types showed that the effects of sowing dates did not vary across locations, but soil types significantly ($p<0.05$) affected the response trend of bread wheat grain and straw yields to sowing dates (Table 1). Grain and straw yield responses of bread wheat to sowing dates over the three locations were significantly ($p<0.001$) and positively linear on *Mererie* soil while the response was quadratic and linear for grain yield and straw yield, respectively, on *Bushella* soil (Table 2). According to previous experiences, regression of mean grain yields of ET-13A_2 bread wheat and local durum wheat cultivars from six sowing dates of 15 days interval starting from 1st July to 15 September in 1983 and 1984 on Vertisols at Enewarie IAR/ADD site [7, 8] also showed quadratic response, increasing grain yield on sowing of 1-31 July but progressively declining thereafter the lowest being from sowing on 15 September, without disaggregating the soil type into *Mererie* and *Bushella*. These quadratic equations significantly ($p<0.05$) explained about 93-94% of the variation in grain yield.

The interaction trend analysis results presented above led to fit the response curves of sowing dates independently for *Mererie* and *Bushella* soils as averaged over the three locations (Goshebado, Deneba and Enewarie) (Fig. 1). The response curves show that grain yield of bread wheat on *Mererie* soil linearly increases with delaying sowing dates; but sowing dates earlier than 17 July and later than 24 July (Table 3) are low yielding on *Bushella* soil and the response curve was quadratic (Fig. 1). Thus late sowing date practices of farmers' on *Mererie* soil is proved to be logical as its clay content is higher than *Bushella* soil (Table 4), higher clay content implies higher water holding capacity that can cause higher waterlogging if not properly drained. Therefore, it seems logical to assume that late sowing reduces the waterlogging duration of the wheat crop and improves productivity at Deneba, Enewarie and Goshebado. Even though the soil drainage method used was not indicated, earlier research result showed that late sowing dates (early August sowing) produced 30% higher grain yields than that of early sowing dates (sowing in late June through July) on Vertisols at Ginchi with the altitude of 2200m asl [9], in the highlands of central Ethiopia, without disaggregating Vertisols into *Mererie* and *Bushella*. Recent research results elsewhere in the highlands of central Ethiopia also indicated that early sowing (3 July) significantly reduced yield of bread wheat on BBF drained heavy black soil [10].

Number of spikes m^{-2} counted in 2007 cropping season, as averaged over the three locations (Deneba, Enewarie and Goshebado) and the two soil

Table 1: Combined analysis of variance results for grain and straw yield in different locations, soil types and sowing dates

Source of variation	DF	Probability for grain yield	Probability for straw yield
Location (L)	2	0.4607	0.0055
Soil type (S)	1	<0.0001	0.1971
Sowing date (SD)	3	<0.0001	0.3404
L*S	2	0.1418	0.0049
L*SD	6	0.5639	0.1274
S*SD	3	0.0035	0.0003
L*S*SD	6	0.3762	0.0111

Table 2: Analysis of variance results for grain and straw yield in different locations and sowing dates at each soil type

		Mererie soil		*Bushella* soil	
Source of variation	DF	Probability level for grain yield	Probability level for straw yield	Probability level for grain yield	Probability level for straw yield
Location (L)	2	0.7806	0.0290	0.2416	<0.0001
Sowing date (SD)	3	0.0001	0.0002	0.0215	0.0179
L*SD	6	0.3355	0.3282	0.4202	<0.0001
SD_{linear}	1	<0.0001	<0.0001	0.5304	0.0048
$SD_{quadratic}$	1	0.2487	0.9980	0.0040	0.1271
SD_{cubic}	1	0.1250	0.5540	0.2975	0.7428

Table 3: Results of mean separation for grain and straw yields on *Mererie* and *Bushella* soils; averaged over three locations and two years

	Mererie soil		*Bushella* soil	
Sowing dates	Grain yield (kg/ha)*	Straw yield (kg/ha)*	Grain yield (kg/ha)*	Straw yield (kg/ha)*
10 July	2679c	4057b	2351b	4795a
17 July	3055bc	4453b	2677ab	4775a
24 July	3814a	5109a	2891a	4606a
31 July	3811a	5506a	2398b	4025b
Standard error of mean difference	224.84	271.63	175.69	250.28

**Means with the same letter in each column are not significantly different using differences of least square means at 5%.*

Table 4: Texture distribution of the two soil types at different sampling depths; averaged over three locations and two years.

	Mererie soil		*Bushella* soil	
Parameters	0-30cm depth	30-60cm depth	0-30cm depth	30-60cm depth
Texture distribution (%)*				
Clay	74.0	72.3	71.0	69.3
Silt	20.0	19.3	21.0	19.7
Sand	6.0	8.3	8.0	11.0
Texture class	Clay	Clay	Clay	Clay

**Hydrometer method*

Table 5: Rainfall amount and distribution of wheat growing period at Enewarie in 2007 and 2008

	Rainfall (mm) in 2007	Rainfall (mm) in 2008	Rainy days in 2007	Rainy days in 2008
1-10 June	10.2	0.0	1	0
11-20 June	60.4	18.0	6	1
21-30 June	22.1	0.0	4	0
1-10 July	52.2	91.0	1	5
11-20 July	103.2	104.4	7	9
21-30 July	86.6	49.5	6	4
31 July-9 Aug.	82.9	126.4	5	8
10-19 Aug.	143.4	135.8	7	7
20-29 Aug.	82.3	72.4	5	5
30 Aug. to 8 Sept.	58.1	99.3	2	7
9-18 Sept.	42.8	1.6	4	1
19-28 Sept.	8.8	0.0	2	0
29 Sept. to 8 Oct.	0.0	0.0	0	0
9-18 Oct.	0.0	0.0	0	0
19-28 Oct.	0.0	0.0	0	0
29 Oct. to 7 Nov.	0.0	47.7	0	4
Total	753.0	746.1	50	51

*No rainfall after 7 November through December

Source: National Meteorology Agency of Ethiopia

Table 6: Two tailed test of Pearson correlation of grain yield with some yield components

		Mererie soil			*Bushella* soil		
		NFS per m^2	SPL (cm)	NSPS	NFS per m^2	SPL (cm)	NSPS
Grain yield	Pearson correlation	0.792	0.547	0.287	0.824	0.409	0.274
	Sig. (2-tailed)	0.000	0.006	0.175	0.000	0.047	0.195
	Number of observations*	24	24	24	24	24	24

NFS is number of fertile spikes; SPL is spike length; and NSPS is number of seeds per spike.

*Number of observations, which is 24, was the result of four sowing dates by three locations by two years.

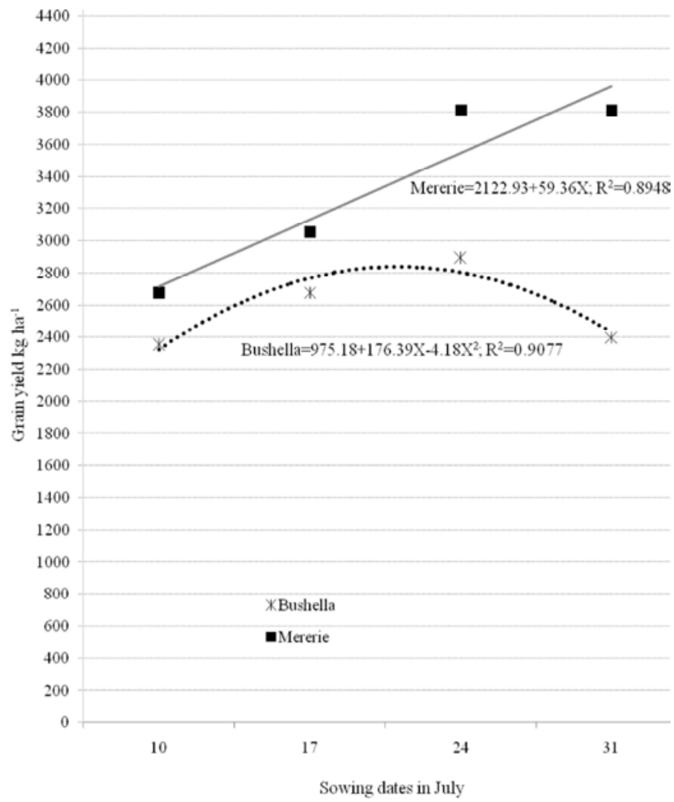

Fig. 1: Effect of soil types and sowing dates on grain yield of bread wheat, averaged over three locations and two years.

types indicated that number of fertile spikes m^{-2} linearly increased while number of non-fertile spikes m^{-2} (spikes hit by *Gasash*) linearly decreased with delaying sowing dates (Fig. 2). *Gasash* was not important problem in 2008. The probable reason for this difference in *Gasash* infestation levels between the two years could be the rainfall distribution (Table 5). In the early sowing and crop establishment period (July) for early sowing dates, the rainfall amount in 2007 was higher than that in 2008 with the same number of rainy days. Moreover, there were higher rainfalls in June of 2007 (92.7mm) than in June of 2008 (18mm) that could have cumulative waterlogging effect in the crop establishment of early sowing dates. Especially the 52.2mm rainfall in the first 10 days of July was poured on 8th of July in 2007 as compared to 10mm rainfall of the same date in 2008. All these poor rainfall distributions in 2007 show that there was relatively higher waterlogging pressure on crop establishment of early sowing dates that enhanced *Gasash* infestation as the result of which higher number of non-fertile spikes m^{-2} was observed in 2007 (Fig. 2). It has also been reported elsewhere that waterlogging causes lower number of spike-bearing tillers per unit area [11, 12]. Thus the inverse relation of number of fertile spikes m^{-2} with early sowing dates accounts for their lower productivity, as fertile spikes m^{-2} are one of the most important yield components in wheat [13]. As indicated in Table 6, Pearson correlation of number of fertile spikes with grain yield was highly significant ($p<0.01$) explaining grain yield variation of about 63% on *Mererie* soil and 68% on *Bushella* soil. Correlation of spike length with grain yield was also significant ($p<0.05$) but the contribution in explaining grain yield variation was very low; only 30% on *Mererie* soil and 17% on *Bushella* soil. Number of seeds per spike did not show significant correlation with grain yield. This finding is also in agreement with farmers' claim that late sowing increases number of fertile tillers per unit area and as well as spike length that all together contribute to higher grain yield.

Field survey on five major wheat growing districts in 2011, including Enewarie and Deneba, in the highlands of central Ethiopia determined the prevalence of *Gasash* to be about 48% at booting and grain filling stage of wheat [14]. This work also identified the associated fungi causing *Gasash* to be *Fusarium sp*, *Sclerotium sp*, *Helminthosporium sp*, *Rhizoctonia sp*, *Gaeumannomyces sp* and *Pseudocercosporella sp* as well as plant parasitic nematodes. However, *Fusarium sp* was dominant followed *Sclerotium sp* and *Gaeumannomyces sp*,

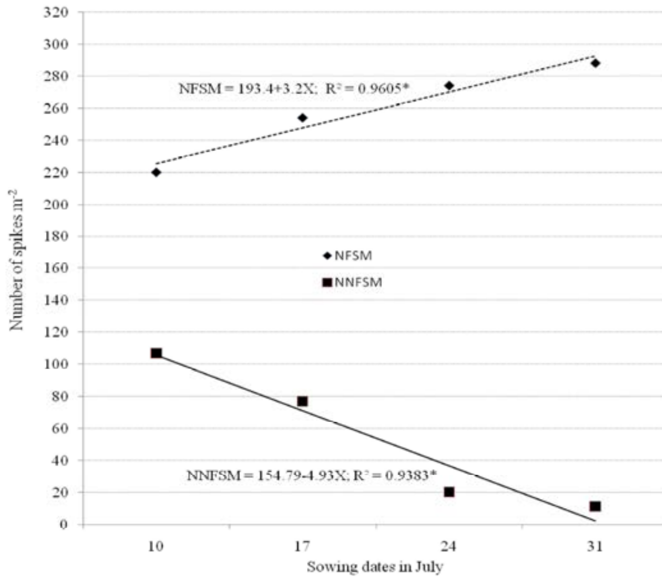

Fig. 2: Effect of sowing dates on number of fertile and non-fertile (hit by gasash) spikes per meter square. **significant at 5% : NFSM is number of fertile spike per meter squre, NNFSM is number if non-fertile spikes per meter square*.

respectively. So far no feasible control measures have been determined other than this sowing date solution. Thus this sowing date experiment findings are very important and need to be promoted widely so as to increase productivity of bread wheat by reducing *Gasash* infestation on Vertisols of Goshebado, Enewarie, Deneba and similar areas in the highlands of central Ethiopia.

CONCLUSIONS AND RECOMMENDATIONS

Depending on the rainfall amount and distribution, early sowing has a risk of waterlogging and *Gasash* infestation that significantly reduce wheat yield in areas like Deneba, Enewarie and Goshebado. The grain yield response curves (Fig. 1) and mean separation (Table 4) indicated that sowing dates ranging from 16 to 26 July on *Bushella* soil and 22 to 31 July on *Mererie* soil are optimum sowing dates for bread wheat in Deneba, Enewarie, Goshebado and similar areas. The use of broad bed maker at Deneba, Enewarie and Goshebado is not recommendable as sowing starts after the soil becomes saturated and/or muddy. These recommended sowing dates significantly reduced *Gasash* infestation and improved bread wheat productivity and hence should be widely promoted.

It is also important to develop waterlogging tolerant varieties if the previous recommendations of early sowing dates and use of BBM are to be returned to practice. Review of prospects for germplasm improvement to waterlogging tolerance in wheat indicates that there is genetic diversity and high heritability of waterlogging tolerance [15]. Additional opportunities are described for increasing genetic diversity using wide hybridizations and development of transgenic plants [16]. It is also important to consider fungicide control measures concurrently with developing waterlogging tolerant varieties if early sowing is to be returned to practice.

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REFERENCES

1. Asamenew, G., S.C. Jutzi, A. Tedla and J. McIntire, 1988. Economic Evaluation of Improved Vertisol Drainage for Food Crop Production in the Ethiopian Highlands. In Management of Vertisols in sub-Saharan Africa. Proceedings of a Conference Held at ILCA, Addis Ababa, Ethiopia, 31 August -4 September. ILCA, Addis Ababa, pp: 263-283

2. McCann, J.C., 1995. People of the Plow: An Agricultural History of Ethiopia, 1800-1990. University of Wisconsin Press. Madison, Wisconsin.
3. Asamenew, G., H. Beyene, A. Haile and W. Negatu, 1993. Technology Transfer and Validation. In Improved Management of Vertisols for Sustainable Crop-Livestock Production in the Ethiopian Highlands: Synthesis Report 1986-92. Technical Committee of the Joint Vertisol Project, Addis Ababa, Ethiopia, pp: 139-146.
4. Pankhurst, A., 2001. Potential for and Constraints on the Use of Broad Bed Maker Technology in Ethiopia. In Advances in Vertisols Management in the Ethiopian Highlands. Proceedings of the International Symposium on Vertisols Management, 28 November to 1 December 2000, Debre Zeit, Ethiopia. EARO, Addis Ababa, Ethiopia, pp: 127-137.
5. Rutherford, A.S., 2008. Broad bed maker technology package innovations in Ethiopian farming systems: An ex post impact assessment. Research Report 20, ILRI (International Livestock Research Institute), Nairobi, Kenya.
6. Fessehaie, R., 2001. Weed Management in Vertisols. In Advances in Vertisols Management in the Ethiopian Highlands. Proceedings of the International Symposium on Vertisols Management, 28 November to 1 December 2000, Debre Zeit, Ethiopia. EARO, Addis Ababa, Ethiopia, pp: 197-207.
7. Institute of Agricultural Research, IAR, 1986a. IAR/ADD Joint Research Program for the Period 1983/84. Addis Ababa, Ethiopia.
8. Institute of Agricultural Research, IAR, 1986b. IAR/ADD Joint Research Program for the Period 1984/85. Addis Ababa, Ethiopia.
9. Tanner, D.G., A. Gorfu and K. Zewdie, 1991. Wheat Agronomy Research in Ethiopia. In Wheat Research in Ethiopia: A historical Perspective, Addis Ababa, IAR/CIMMYT, pp: 95-135.
10. Molla, A., 2013. Farmers' Knowledge Helps Develop Site Specific Fertilizer Rate Recommendations, Central Highlands of Ethiopia. World Applied Sciences Journal, 22(4): 555-563.
11. Belford, R.K., R.Q. Cannell and R.J. Thomson, 1985. Effect of Single and Multiple Waterlogging on the Growth and Yield of Winter Wheat on a Clay Soil. Journal of the Science of Food and Agriculture. 36: 142-156.
12. Sharma, D.P. and A. Swarup, 1989. Effect of Nutrient Composition of Wheat in Alkaline Soils. Journal of Agricultural Science (UK). 112: 191-197.
13. Bell, M.A. and R.A. Fischer, 1994. Guide to Plant and Crop Sampling: Measurements and Observations for Agronomic and Physiologic Research in Small Grain Cereals. Wheat Special Report No. 32. Mexico, D.F.:CIMMYT.
14. Bitew, B., 2012. Importance and Etiology of Premature Drying of Wheat and Reaction of Popular Bread Wheat *(Triticum aestivum* L.) Cultivars in North Shewa Highlands. MSc Thesis, Haramaya University.
15. Setter, T.L. and I. Waters, 2003. Review of Prospects for Germplasm Improvement for Waterlogging Tolerance in Wheat, Barley and Oats. Plant and Soil 253: 1-34.
16. Van Ginkel, M.S. Rajaram and M. Thijssen, 1992. Waterlogging in Wheat: Germplasm Evaluation and Methodology Development. In Seventh Regional Wheat Workshop for Eastern, Central and Southern Africa. Nakuru, Kenya: CIMMYT, pp: 115-124.