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DRY WEIGHT OF SPIKE AT ANTHESIS DETERMINES GRAIN WEIGHT OF SPIKE AT MATURITY

Habib Akbar[1], Mohammad Idrees[1], Mian Furqan Ahmad[2], Mohammad Arif[1] and Mohammad Zakirullah[1]
[1]Department of Agronomy, NWFP Agricultural University Peshawar, Pakistan
[2]Department of Soil and Environmental Sciences, NWFP Agricultural University Peshawar, Pakistan
E-mail: aup_idrees@yahoo.com

ABSTRACT

An investigation relating to planting geometries i.e. solid, skip under 100, 150kg N ha^{-1} on dry matter of wheat S.W.10, Bakhtawar and Inqilab varieties were conducted at Research Farm of NWFP Agricultural University, Peshawar during winter 2002. Planting geometry and N integrated were allotted to the main plots and wheat varieties to sub-plots in logical structure Randomized Complete Block (RCB split plots arrangements). Design having five replications was used. Spike dry weight and leaf dry weight at anthesis were significantly affected by planting geometries. Maximum spike dry weight for 10 tillers at anthesis of 5.76g was recorded for skip geometry followed by 4.94g for solid. Sheath and stem dry weight were significantly affected by planting geometries and N. Maximum of 5.01g dry sheath weight was recorded for skip geometry where as minimum of 4.54g observed for solid geometry. For N maximum of 4.93g was noted for 100kg N ha^{-1} while minimum of 4.61g was observed for 150kg N ha^{-1}. Maximum of 15.22g was noted for skip geometry where as minimum of 13.89g was recorded for solid geometry. Maximum of 15.27g was recorded for 100kg N ha^{-1} while minimum of 13.83g in 150kg N ha^{-1}. Dry matter of 10 tillers leaves, sheaths and stems weight at maturity showed no response to planting geometry and N. Spike dry and grain spike^{-1} weight of 10 tillers at maturity were significantly affected by planting geometry. Maximum of 28.01g 10 spikes weight including grains at maturity was recorded for skip geometry followed by 25.13g for solid geometry spike. Maximum of 20.82g grain spike^{-1} weight was recorded for skip geometry while minimum spike grain weight of 18.9g for solid geometry. It is concluded that after anthesis spike-lengthening spikelets and fertile florets growth continued besides chaff add to spike weight. Spike grain weight is approximately 3-4 times greater at maturity than spike weight at anthesis. Pre and post anthesis leaf lamina and non-leaf structures of inflorescence continue photosynthesis contribute continuously to spike dry matter and dry weight up to maturity. Pre and post anthesis photosynthesis contribute to spike weight.

Keywords: wheat, variety, planting, geometry, spike, dry weight, anthesis, maturity.

INTRODUCTION

Once the terminal spike is formed inside boot stage, peduncle elongation starts and the spike begins to grow. Spike growth occurs from the appearance of the leaf prior to the flag leaf (penultimate leaf) up to ten days post anthesis (Kirby and Appleyard, 1984). Spike development in early stages, increases greatly about the time the ligule of the flag leaf becomes visible (Krumm *et al*., 1990). Optimum radiation increases the amount of photosynthates available for spike growth, and lower temperatures prolong the period of spikelets growth and decrease competition for carbohydrates. Meiosis in wheat, which originates (double ridge stage) the pollen in the anthers and the embryo sac in the carpel, coincides with the boot stage. This stage is very sensitive to environmental stresses. In wheat and barley, meiosis starts in the central florets of the spike, continuing later below and above this zone (Zadoks *et al*., 1974). Wheat spike contains only one spikelet per rachis node or notch. Each spikelet bears four, three to seven potentially fertile florets (Kirby and Appleyard, 1984), which are self-pollinated in 96 percent of the cases in concealed glumes (Martin et al., 1976).

Anthesis first begins in the central part of the spike and continues towards the basal and apical parts during a three- to five-day period (Peterson, 1965). The proximal florets of the central spikelet are fertilized two to four days earlier than the distal florets. These grains usually have a greater weight (Simmons and Crookston, 1979). Grain number produced per unit land area is mainly set at anthesis (flowering), when the numbers of fertile florets are determined. The late reproductive phase or stem elongation phase occurring a few weeks before anthesis (from terminal spikelet initiation to anthesis) is of paramount importance in determining the number of fertile florets at anthesis (Fischer 1984 and Fischer 1985, 1993). Wheat yield could be improved by increasing the spike dry weight at pre-anthesis through a longer duration of stem elongation (Slafer *et al*., 1996). In wheat, grain number is established at around the time of anthesis. Strong competition between the growth of the spike and vegetative sinks during 20–30 days before anthesis could affect florets survival and, then, grain number in wheat at maturity (Fischer, 1984; Miralles *et al*., 1998).

Spike dry matter at anthesis reflects the peak quantity of assimilates invested in reproductive growth and several authors have found a linear relationship between spike biomass at anthesis and number of grains in wheat crops when water and nutrients were not limiting growth (Fischer, 1985., Savin and Slafer, 1991., Abbate *et al*., 1997). Filled grain results under sink and source adequacy, limitation due to sinks size and number limit grain potential at maturity. Nitrogen deficiencies diminish grain number and yield both in wheat and barley (Fischer, 1993., Baethgen *et al*., 1995). , Fischer (1993) observed that in wheat crops subjected to different N fertilization treatments grain number was related to spike biomass around anthesis. On the other hand, Abbate *et al.* (1995) found that grain numbers were related to spike N better non-leaf structure contribute than to spike biomass at anthesis, while Demotes-Mainard *et al*. (1999) observed that grain number was related to both spike N and biomass at anthesis. Spike N and biomass at anthesis could be seen as the consequence of two processes: accumulation of biomass and N in the above ground part of the plant during pre-anthesis and their partitioning between the vegetative organs and the spike fertile florets (Demotes-Mainard and Jeuffroy, 2001). In nitrogen stressed wheat the proportion of above ground biomass in the spike has been found to be lower (Abbate *et al.*, 1995). And the proportion of above ground N in the spike has been increased or not affected by N deficiency in wheat (Demotes-Mainard and Jeuffroy, 2001; Przulj and Momcilovic 2001; Golik, *et al*. 2003.). Similarly impact of N fertilization on N partitioning to spikes has been addressed in wheat by (Fischer, 1993; Abbate *et al*, 1995; Demotes-Mainard and Jeuffroy, 2001). Grain yield is a function of interaction between genetic and environmental factors, inputs and their management like soil type, sowing time and method, seed rate, fertilizers and time of irrigation. Among these factors planting geometry plays a vital role in getting higher grain yield. Wheat is generally planted by broadcast method by most of the farmers in the country and only progressive farmers and researchers use line sowing. Now a day due to infestation of weeds, it has become necessary to sow the crop in lines with a suitable row spacing, which may help in cultural operations, herbicides application, inter-cropping and increasing or decreasing seed rate without any adverse effect on the final grain yield. Proper planting geometry as predictive device is imperative for maximizing light interception, penetration, distribution in crop canopy and average light utilization efficiency of the leaves in the canopies, and thus affect yield of a crop. Wider spacing between rows or pairs of rows, not only allow more light to reach the lower leaves at the time of grain formation but also allows easy inter-culture for weed control and inter-cropping (Ayaz *et al.*, 1999). Similarly Nazir *et al.* (1987), Shafi *et al.* (1987) and Surendra *et al.* (1985) concluded that wheat grain yield was not reduced to a significant extent by increasing the row spacing. Wider planting geometry increase tillering. More mother tillers in the form of plumpy bigger grain in solid rows resemblance with more tillers with small sinks but larger in number. In skip compensate appreciably technology without any risk of reduction in yield, may facilitate inter-tillage devices for effective weed control and intercropping in wheat.

MATERIALS AND METHODS

The present study was conducted at Agricultural Research Farm, NWFP Agricultural University, Peshawar during winter 2002. Logical structure RCB (V split on PG integrated N) was used. . The area is located at 34^0 $01^{'}$ N latitude 71^0 $33^{'}$ E longitudes and an elevation of 450m above the sea level. The soil of the site was clay loam texture low in NPK, organic matter and alkaline with high pH calcareous in nature. A basal dose of P @ 60kg ha^{-1} was applied at the time of sowing. Particulars of the experiment were as follows:

- **Planting geometries:** Solid row geometry and skip row geometry.
- **Nitrogen rate:** N_1, 100kg ha^{-1} and $N_{2,}$ 150kg ha^{-1}
- **Wheat varieties:** V_1, S.W.10, V_2, Bakhtawar and V_3, Inqilab.

For N and P urea and TSP were used as source, respectively. Data was recorded on the following parameters. At peak anthesis 10 productive representative tillers were taken, dried and weighed for dry weight of spike (without grain at anthesis), stem, leaves and sheath individually. At maturity the same were repeated especially for difference at anthesis dried weight of spike with weight of spike at maturity as remobilization was assessed. Following parameters were studied:

At anthesis	At maturity
1. Spike dry weight without grain (g)	5. Dry weight of spike (g)
2. Dry weight of leaves (g)	6. Dry weight of leaves (g)
3. Dry weight of sheaths (g)	7. Dry weight of sheaths (g)
4. Dry weight of stems (g)	8. Dry weight of stems (g)
	9. Dry weight of grain (g)

Data was statistically analyzed according to RCB design, split plot arrangements (Steel and Torri, 1980). Analysis of variance and LSD was used accordingly.

RESULTS AND DISCUSSION

Spike dry weigh without grain at anthesis (g):

At anthesis (pollen extrusions) spike dry weight (g) of skip geometry was found better than solid. Table-1 showed that maximum ten spike dry weight of 5.76g was recorded for skip geometry followed by 4.94g for solid geometry might be less competition for light because there were less number of plant and low inter and intra competition. Floret survival would enhance increasing spike dry weight at anthesis through a longer duration of spike growth period mostly coinciding with stem elongation phase, from terminal spikelet initiation to anthesis. (Slafer *et al*. 1996, 2001). Higher radiation increases the amount of photosynthates available for spike growth, and lower temperatures prolong the period of spikelet growth and decrease competition for carbohydrates (González, *et al*. 2003). Miralles *et al.*

(2000) supported the idea that the number of fertile (floral essential parts) florets depends upon pre-anthesis amount of assimilates partitioned to the spikelets florets. Spike dry matter at anthesis reflects the quantity of assimilates invested in reproductive growth and several authors have found a linear relationship between spike biomass at anthesis and number of grains in wheat crops when water and nutrients were not limiting growth (Fischer, 1985; Savin and Slafer 1991; Abbate, *et al*. 1997).

Dry weight of leaves at anthesis (g):

Mean values for 10-tiller dry leaves weight at anthesis treatment given in Table-1 revealed that planting geometry have significantly affected dry leaf weight. Maximum of 4.68g was observed for the skip geometry while minimum of 4.28g was noted for solid geometry. Plant compete each other for light, moisture, nutrient and space the reason might be less competition among the plants or might be efficient utilization of space and environmental factors such as change in the spectrum of solar radiation reaching the lower layers due to which more photosynthesis and assimilate availability in the leaves which resulted more dry leaf weight at anthesis. Dry matter partitioning to leaves decreased throughout the growth season while to that of stem increased up to anthesis and there after it decreased up to physiological maturity (Singh *et al*., 2004.)

Dry sheath weight at anthesis (g):

Sheaths dry weights for ten tillers at anthesis were significantly affected by planting geometry and N treatments (Table-1). The meditation of data in Table-1 shows that maximum of 5.01g dry sheaths weight was recorded for skip geometry where as minimum of 4.54g was observed for solid geometry. For N maximum of 4.93g was noted for 100kg N ha^{-1} while minimum of 4.61g was observed for 150kg N ha^{-1}. The reasons may be that maximum sheath dry weight at anthesis due to Proper row spacing is important for maximizing light interception, penetration, distribution in crop canopy and average light utilization efficiency of the leaves in the canopy, and thus dry matter affect ed. Wider spacing between rows or pairs of rows, not only allow more light to reach the lower leaves at the time of grain formation but also allows easy inter-culture for weed control and inter-cropping (Ayaz *et al*., 1999). Similarly Nazir *et al*. (1987), about half of the dry weight of the sheath comes from sources other than attached lamina or subtending leaf. The accumulation of dry matter and N in the aerial parts of the plant, and their partitioning between the spike and the vegetative parts throughout the spike growth period (partitioning between shoots). (Abbate *et al*., 1995; Demotes-Mainard *et al*., 1999).

Dry stem weight at anthesis (g):

10-tillers stem dry weight at anthesis was significantly affected by geometry and N treatments. The results show that maximum of 15.22g was noted for skip geometry where as minimum of 13.89g was recorded for solid geometry. Maximum of 15.27g was recorded under 100kg N ha^{-1} while minimum of 13.83g at 150kg N ha^{-1}. Some varieties that perform well in wide rows tend to be either tall by nature or grow tall due to favorable weather. They also have a non-erect growth habit that allows them to fill in the wide row middles, which will also compensate for skips in the row or low population (Jim Beuerlein, 2001). Nitrogen application increased vegetative growth due to maximum growth more carbohydrate and more dry weight at anthesis. The durations of vegetative and stem elongation phases could be independently manipulated to improve wheat yield without modifying the timing of anthesis (Slafer *et al*., 2001).

Table-1. Ten tillers spikes, leaves, sheaths and stems dry weights (g) at anthesis as affected by planting geometry, nitrogen and wheat varieties.

Factors	**10 Spikes dry without grains weight** (g)	**Dry leaves of 10 tillers weight** (g)	**Sheaths of 10 tillers dry weight** (g)	**Stems of 10 tillers dry weight** (g)
Solid	4.94 b	4.28 b	4.54 b	13.89 b
Skip	5.76 a	4.68 a	5.01 a	15.22 a
N1,100kg N ha^{-1}	5.53	4.48	4.93 a	15.27 a
N2,150kg N ha^{-1}	5.17	4.47	4.61 b	13.83 b
V1, S.W.10	5.36	4.32	5.02	14.62
V2, Bakhtawar	5.46	4.36	4.63	13.33
V3, Inqilab	5.23	4.75	4.65	14.94
LSD for PG	**0.82**	**0.78**	**0.47**	**1.33**
LSD for N			**0.32**	**1.44**

PG = Planting geometry
Mean values followed by different letter(s) in each category are significantly different at 5% level of significance.

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Spike dry weight at maturity (g):

At maturity ten spike dry weights (including grains) of skip geometry were found better than solid. As shown in Table-2, maximum of 28.01g was recorded for skip geometry followed by 25.13g for solid geometry. When duration of stem elongation was lengthened by exposure to natural photoperiod and when incident radiation was high, spike dry weight at anthesis increased (Gonzalez, *et al*. 2005). Yield components vary when crops are planted in different spatial arrangements because the later affect the morphology and development of the plants (Marshall and Ohm, 1987, Jhonson, *et al*. 988). It has been suggested that wheat yield could be improved by increasing the spike dry weight at anthesis through a longer duration of stem elongation (Slafer *et al*., 1996). It was also suggested that longer duration of stem elongation would increase spike dry weight due to higher accumulated intercepted radiation during that period (Slafer *et al*., 2001). Pre and post anthesis photosynthesis contribute to spike weight.

Dry leaves weight at maturity (g):

Mean values for 10 tillers leaf dry weight at maturity treatments (Table-2) indicated that planting geometry, N and varieties have not significantly affected dry leaf weight, however maximum of 3.62g was observed for the variety (S.W.10) while minimum of 3.14g was noted for variety (Inqilab). The decline in leaf and stem weight at later reproductive phase and maturity resulted in translocation of pre-anthesis assimilates stored in these plant parts to the developing grains (Singh *et al*., 2004).

Ten tillers dry sheaths weight at maturity (g):

Data regarding sheath dry weight at maturity (Table-2) showed that the planting geometry, N and varieties had not significantly affected sheath dry weight at maturity. However maximum value of 4.56g was observed for the variety (S.W.10) followed by 4.21g for variety (Bakhtawar). Since there was about half of the dry weight of the sheath come from source unknown, other than attached lamina and low assimilate stored in sheath and stem before anthesis are available for grain filling after anthesis in stress condition.

Ten-dried stems weight at maturity (g):

The statistical analysis of data relating to stem dry weight at maturity (Table-2) showed that planting geometry, N and variety had no significant affect on stem dry weight at maturity. But maximum of 14.15g was noted for variety (Inquilab) followed by minimum of 12.66g for variety (Bakhtawar). It may be due to the decline in leaf and stem weight at later reproductive phase and maturity resulted in translocation of pre-anthesis assimilates stored in these plant parts to the developing grains. (Singh *et al*., 2004). At maturity, water-soluble carbohydrate levels in stems decreased (Yong-Zhan *et al*., 1996).

Table-2. Ten tillers Spikes, leaves, sheaths, stems and spike's grain dry weight (g) at maturity as affected by N, planting geometry and varieties.

Factors	**10 spikes dry weight** (g)	**10 tillers dry leaves weight** (g)	**10 tillers sheaths dry weight** (g)	**10 tillers stems dry weight** (g)	**10 spikes (grain only) weight** (g)
Solid	25.13 b	3.31	4.30	13.63	18.90 b
Skip	28.01 a	3.45	4.40	13.63	20.82 a
N1, 100kg N ha^{-1}	27.06	3.47	4.48	13.45	20.35
N2, 150kg N ha^{-1}	26.09	3.29	4.22	13.81	19.37
V1, S.W.10	26.18	3.62	4.56	14.07	20.29
V2, Bakhtawar	27.59	3.38	4.21	12.66	20.18
V3, Inqilab	25.95	3.14	4.25	14.15	19.11
LSD for PG	**2.88**	**NS**	**NS**	**NS**	**1.92**

NS = Non-significant
PG = Planting geometry
Mean values followed by different letter(s) in each category are significantly different at 5% level of significance.

Ten Spike grain weight at maturity (g):

Planting geometry had significantly affected spike grain weight at maturity. Maximum of 20.82g was recorded for skip geometry while minimum of 18.90 was recorded for solid geometry. Wheat development has been widely studied to understand environmental adaptation and its consequence on grain yield (Slafer and Rawson, 1994**.** However, the variability in the yield response to row spacing depends to a great extent on the genotype and the environment (Marshall and Ohm, 1987). Another explanation may be the availability of nutrients in the larger inter-row space during the grain-filling period (anthesis to maturity) in wider row compared to narrow row (Baeumer, 1992 and Lafond, 1994). The results showed that genetic difference was the main factor affecting grain-filling characteristics, while nitrogen fertilization had a less effect. Spike dry matter at anthesis reflects the quantity of assimilates invested in reproductive growth and several authors have found a linear relationship between spike biomass at anthesis and number of grains in wheat crops when water and nutrients were not limiting growth (Fischer, 1985, Savin and Slafer, 1991

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and Abbate *et al.*,1997). Considering that grain number is closely associated with the number of fertile florets at anthesis increasing spikelet rachilla rachis (florets stalk) fertility to improve wheat yield potential (Araus *et al.*, 2002).

Table-3 shows that the approximate mean ratio of spike dry weight at anthesis, spike dry weight at maturity and grain weight is 1: 4.966: 3.71. It indicates that by subtracting spike dried weight from maturity, spike grain weight increased manifold on account of continuous spike spikelets, florets and grain growth. Post anthesis growth also contributed to spike dry matter and spike dry weight rather than pre-anthesis as well.

Table-3. Spike weight (g) difference at anthesis and post anthesis (maturity) in spike dry mater and dry weight, respectively (derived data).

Factors	**10 tillers Spikes wt at anthesis** (g) **(SWA)**	**10 tillers spikes wt at maturity** (g) **(SWM)**	**10 tillers spikes (grains wt only) at maturity** (g) **(GWM)**	**Spike (inflorescence dry wt only) at maturity** (g) **SDWTM= (SWM-GWM)**	**Post anthesis inflorescence dry wt gained** (g) **at maturity (SDWTM-SWA)**
Solid Skip	4.94 5.76	25.13 28.01	18.90b 20.82a	6.23 7.19	1.29 1.43
N1, 100kg N ha^{-1} N2, 150kg N ha^{-1}	5.53 5.17	27.06 26.09	20.35 19.37	6.71 6.72	1.18 1.55
V1, S.W.10 V2, Bakhtawar V3, Inqilab	5.36 5.46 5.23	26.18 27.59 25.95	20.29 20.18 19.11	5.89 7.41 6.84	0.53 1.95 1.61
Average	**5.35**	**26.57**	**19.86**	**6.71**	**1.36**
Ratios	**1**	**4. 97**	**3.71**		

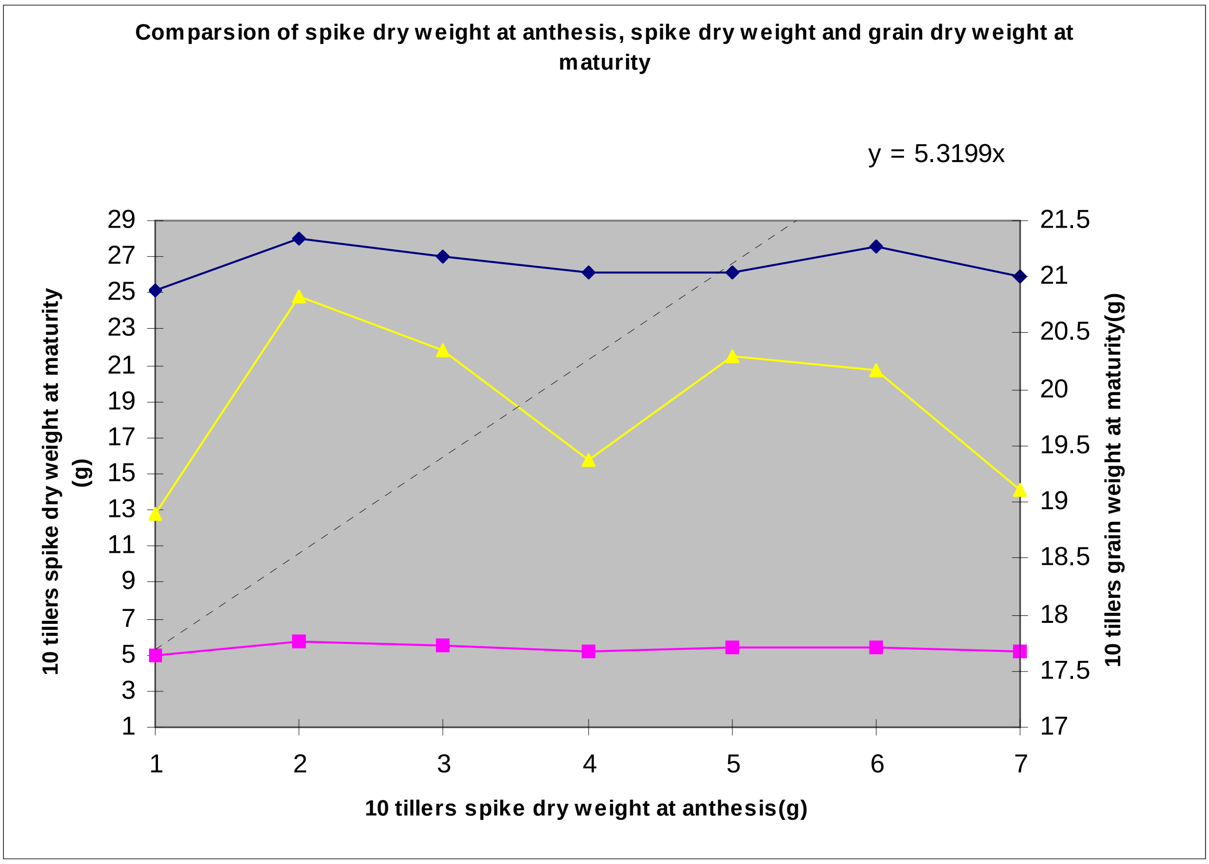

Figure-1. Comparison of spike dry weight (g) at anthesis, spike dry weight (reproductive structures having grains) and spike grain weight only at maturity.

CONCLUSION

Maximum grain weight at maturity is the outcome of maximum dry matter at anthesis. Dried weight of spike at anthesis approximately 4-5 times is less than to grain weight of spike at maturity. Planting geometry i.e. skip contributed up to greater extent than solid to spike dry matter and dry weight respectively. Indeterminate terminal in florescence non-leaf structures do contribute proportionally as well. Table-3 shows that the approximate mean ratio of spike dry weight at anthesis, spike dry weight at maturity and grain weight is 1: 5: 4. It indicates that by subtracting spike dry matter weight at anthesis from maturity, spike grain weight manifold four times on account of continuous spike spikelets, florets and grain growth. Conclusively, dig a well before the thirst overtakes the crops. Don’t throw rocks (N) in the Horne’s nest.

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