165 Tillage and Planting Strategies for Sandy Soils in Niger, West Africa

Willem B. Hoogmoed and Michiel C. Klaij
Soil Tillage Laboratory, Agricultural University, Wageningen, The Netherlands
and ICRISAT Sahelian Center, Niamey, Rép. du Niger

Introduction

The Sahelian zone is characterized by harsh conditions for crop growth: chemically and physically poor soils, low and uncertain rainfall, and high temperatures. Crops are particularly sensitive to the physical environment during the germination and seedling stages of crop establishment. Appropriate soil management techniques reduce the risk for crop failure and help to ensure good crop stands.

The effects of improved cultural practices on soil physical characteristics as well as the time that is required and available to accomplish land preparation and planting operations are discussed in this paper.

The Physical Environment

The Sudano-Sahelian zone of West Africa is characterized by a steep gradient in annual rainfall from 400 mm in the north to 1000 mm in the south. The rainy season is mono-modal with rains beginning in May-June, the highest rainfall in July-August, and ending in September-October. Rainfall is the most variable environmental parameter. Rain intensities are high, often exceeding 100 mm/h.

In the beginning of the season, rainfall generally occurs in fairly isolated convective storms. They are often followed by clear hot days with a high evaporative demand. From 1983 to 1987, the daily pan evaporation following a rainfall event before July 15 ranged between 9 and 11 mm. This results in a very rapid desiccation of the soil surface.

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is the major staple crop in the region. It is grown on an estimated 14 million ha in the Sahelian and Sudanian ecological zones. Although the area on which millet is cultivated has grown over the last 25 years, average yields have dropped from 0.5 Mg/ha to 0.3 Mg/ha. The expansion of the cultivated area into more marginal lands with lower inherent fertility and a reduction of the area under and duration of fallow periods have contributed to this decline.

The principal factors limiting increased yields are, in order of priority: inherently low soil fertility, limited and untimely cultural practices, and the occurrence of drought periods (Fussell et al., 1987).

The dryland agricultural soils in the study region are Alfisols: sandy soils, classified as Psammentic Paleustalfs (U.S. taxonomy). They contain approximately 90 g/kg sand, 5 g/kg silt, and 5 g/kg clay in the A-horizon (top 30 cm). They are chemically very poor, with a cation exchange capacity of 0.013 mol/kg, and a base saturation of 42%. The pH (H_2O) is low, 4.9. The water holding capacity of the soil is very low (approximately 0.11 cm^3/cm^3 at field capacity and 0.02 cm^3/cm^3 at permanent wilting point). Sustained infiltration rates on undisturbed soils exceed 100 mm/h. The hydraulic conductivity near saturation is also very high, 150-200 cm/day at saturation. The top 10 cm of the soil profile reaches field capacity within a few hours after a rainfall event.

The sandy soil is poorly structured with little cohesion. Tillage operations when the soil is dry do not leave clods, but rather tend to destroy what structure there is and result in a loose powdery soil that is susceptible to wind erosion. Unlike sandy soils elsewhere in the Sahel, consolidation of the soil as a result of natural forces (rainfall, wind, and radiation) is limited. As the soil dries, there is no strong soil hardening. Field experience indicates that tillage is most effective when the soil is moist. Ridging or plowing moist soil leaves larger aggregates that are stable after drying, due to a combined smearing and compaction effect. There is no maximum water content limiting the workability of the soil.

A stable surface layer is important after planting, when blowing sand may cause considerable damage to seedlings. Laboratory experiments (Hoogmoed, 1986b) showed that the higher the water content associated with soil compression, the greater the resulting soil strength. Tillage operations for seedbed preparation and surface stabilization are less effective when the soil water content drops below 0.08 cm^3/cm^3.

The Time Factor in Tillage and Planting

Timely planting of millet at the onset of the rainy season is critical to good crop establishment and has a major influence on final yields.

It is well known that yields are reduced as plantings are delayed after the first rains. Although the reasons for this are not well understood, it is thought that higher levels of available nitrogen associated with the onset of biological activity and mineralization after a dry period is one of the principal causes. Higher yields associated with early planting motivate farmers to plant early despite risks of failing to establish a stand. Farm labor is not needed for other activities at this time of the year and, should the planting fail, the loss of the seed is small (5-12 kg/ha). The above situation applies for the traditional "no-tillage" crop production system, where there is no seedbed preparation, but just opening holes with a hoe and planting seeds in these holes. There is, on the other hand, a great deal of evidence that soil tillage improves the emergence, crop establishment, water use efficiency, and yield of millet (Klaij and Hoogmoed, 1987; ICRISAT, 1986; ICRISAT, 1987). These effects are enhanced by the use of fertilizers.

There are often only limited periods available for soil preparation and planting in the Semi-Arid Tropics (SAT) because of the erratic rainfall patterns associated with the onset of the rainy season. The first rains that fall on a dry soil wet the profile 10 to 12 mm for every mm of precipitation. Tillage operations are possible when the top 10 cm of the soil is moist.

Experience and observations in the region indicate that 13 to 20 mm of rainfall on 1 or over 2 consecutive days is the minimum necessary to ensure good germination and seedling survival for 10 to 14 days. In general, tillage operations can be carried out after less rain than that required for planting. Thus it is possible to define three types of rainfall situations that may occur at the beginning of the season:

- rainfall that is insufficient for either tillage or planting,
- rainfall that is sufficient for tillage but insufficient for planting, and
- rainfall that is sufficient for both tillage and planting.

To consider the introduction of improved soil management practices it will be necessary to know:

a. How many days are available for the tillage and planting?
b. How many planting days will be "lost" to tillage operations?

An analysis of the rainfall data for three representative locations in Niger (Tahoua, Niamey, and Gaya) with average annual rainfall ranging from 380 to 825 mm was made (Hoogmoed, 1988a) to enumerate the occurrence of early season rainfall events that would permit tillage and/or planting and the planting delays that would result from the introduction of pre-plant tillage.

The assumptions that were used to determine when days were acceptable for tillage operations or planting are presented in Table 1. Both for tillage and planting, three rainfall size classes are distinguished, assuming 2 to 3 workable days in a "pessimistic" scenario and 2 to 4 days in an "optimistic" scenario. Only one scenario was used for the calculation of plantable days, assuming 1 to 3 days available. The analysis was carried out over the soil preparation and planting period that is typical of the season. The period began May 1 for all locations and ended June 28 for Tahoua, July 18 for Niamey, and July 28 for Gaya. Planting after this period was assumed not to have left enough rainy season to expect any harvest.

The probabilities of rainfall events that will permit tillage and planting within these periods at these sites is presented in Table 2. Extra days are available for tillage in only 22% of the years at Tahoua and 39% of the years at Gaya; that is, in these years the first planting rain will be preceded by rain events allowing for tillage. The first rains permit both tillage and planting more frequently, 41% and 81% at Tahoua and Gaya, respectively. In 28% of the years, there are no rainfall events large enough to satisfy the threshold limit for planting in Tahoua. In the wetter locations, there are always 2 or more days available for planting.

The number of days when tillage and planting is possible is given in Table 3. The column "extra" indicates the number of days available for tillage before the first day when it is possible to plant. This is an average

Table 1. Assumed rainfall thresholds and resulting numbers of workable and plantable days.

Tillage rainfall threshold		Workable days (WD)[a]	
in 1 day	in 2 consec. days	pessimistic	optimistic
mm		no.	
8	10	2	2
16	18	2	3
23	25	3	4

Planting rainfall threshold		
in 1 day	in 2 consec. days	Plantable days (PD)[b]
mm		no.
13	18	1
21	26	2
28	33	3

[a] Workable day (WD) = a (full) day during which the soil water content allows tillage operations.
[b] Plantable day (PD) = a (full) day during which planting of millet is feasible, and the soil water content and the time elapsed since the rainfall event are favorable.

Table 2. Probabilities (%) of availability of workable and plantable days.

	Situation[a]				
Location	1	2	3	4	5
Tahoua	8	20	9	22	41
Niamey	0	0	0	41	59
Gaya	0	0	0	39	61

[a] The situations are:
1 = There are no workable or plantable days.
2 = There are only workable days, no plantable days.
3 = The first workable day coincides with first plantable day, but there are no more plantable days.
4 = Extra workable days occur before the first plantable day.
5 = The first workable day coincides with first plantable day, more workable and plantable days follow in this period.

Table 3. Number of workable (WD) and plantable days (PD), calculated for three locations, based on the assumptions given in Table 1.

Location	Annual rainfall	Years analyzed	Situation							
			Optimistic				Pessimistic			
			WD	PD	WD-PD	Extra[a]	WD	PD	WD-PD	Extra
	mm		no.							
Tahoua	384	64	7.2	2.7	4.5	3.0	6.3	2.7	4.4	2.9
Niamey	559	79	19.6	9.4	10.2	2.8	16.7	9.4	7.3	2.8
Gaya	825	54	35.1	19.1	16.0	2.8	30.2	19.1	11.1	2.8

[a] Applicable for Tahoua, Niamey, and Gaya in 22, 41, and 39% of the years, respectively.

number based only on those years when this situation occurs. In all other years, no extra days are available.

These analyses indicate that the number of days that are available for essential farm operations are often particularly limited in dry years where timely planting, if it is possible at all, may be of crucial importance. It was found that in approximately 40% of the years at Tahoua, 5 days or less are available for tillage. In another 40%, 8 to 10 days are available. At Niamey, more than 10 days are available for tillage in 90% of the years and, in another 7% of the years, 6 to 10 days are available. There are always more than 10 days available for the tillage operations in Gaya. Labor availability and the time requirements of the various operations will determine the areas that may be cultivated and cropped using a given set of techniques.

Time Requirements

The following time requirements have been found for tillage and planting operations on sandy soils in the Sahelian region:

- tillage (i.e., ridging with an animal-drawn ridger or moldboard plow): 15 to 20 person-hours per ha (one person with a team of animals),
- hill planting (opening "pockets" spaced 1.5 m x 1.5 m with a hoe, planting some seeds by hand, and closing the seed pocket with the foot): 8 person-hours per ha (usually a 2-person task).

This indicates that ridging would take at least 2 days/ha. The time required for seedbed preparation is not necessarily lost if there is sufficient labor to plant while using a pair of animals and a tillage implement for pre-plant tillage. In this case, the time between tillage and planting should be as short as possible, a matter of hours in sunny conditions, because the topsoil that has been disturbed will dry out very quickly.

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