DIRECT DRILLING IS BEHIND AGRONOMY OF OPPORTUNITY IN TUNISIA

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ABSTRACT

Tunisian climate is mediterranean, characterized by irregular, sudden, intense and relatively low rain-fall. Land degradation is continuing, water resources are becoming scare, and energy cost of farm products is continuously getting high. Consequently, cereal producers can hardly make an economic return, while practicing conventional agriculture based on conventional drilling (CD). Conservation agriculture based on direct drilling (CA/DD) gives farmers a chance to protect soils and rebuilt their fertility for an efficient use of any available form of water (rain-fall, irrigation). Such desirable efficiency does not come only by the use of the appropriate crop species, but necessarily by reducing water evaporation. To do so, a permanent mulching on the soil surface is the pivot of CA/DD. Since rain-fall fluctuates from one year to another, crop sequences should parallel with such conditions. Some couloirs have early rains (September-October) and late rains (May-June) too. In Bou-Salem (Governorate of Gendouba), early and late rains accounted for 26.2 % and 19.9 % of the 07/08 total rain for cereal growing season (September/07-June/08), respectively. These rains are not well capitalized in cereal production, when applying conventional agriculture. So, coupling the site specific approach and agronomy of opportunity is imperative to lift up farm productivity.

The climate (rain, heat) of production sites should be characterized to better define growing seasons and make the appropriate agronomic sequence. Then, the agronomy of opportunity (producing the maximum of biomass whenever the climate and the biology of the desired crop are favorable) could be applied in different scenarios, under rain-fed and/or irrigation conditions. There is no static scheme to crop the land, and it is rather a dynamic management of soil, crops, and water. A particular emphasis should be put on use of strictly seasonal (fall, winter, spring, summer) cereals and legumes in order to make a continuing cropping with two-three crops a year. A potential scenario could be a fall-barley/spring-peas/summer short season-sorghum hybrid.

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Actually, few crops [barley (*Hordeum vulgare*), oat (*Avena sativa*), sorghum (*Sorghum bicolor*), millet (*Pennisetum glaucum*), african Luzerne (*Medicago sativa*)] are used as cover crops and others still under experimentation. So, AC/DD is a new ag-technology using the same species cropped in conventional agriculture but sometimes for a very different purpose. For example, barley may be sown first to be grazed, then according to the rain-fall a farmer has the choice to keep grazing or remove his flock out of the field and either seed a spring crop or let barley plants go to grain filling stage. Therefore, barley becomes a multipurpose crop when applying agronomy of opportunity. Some agronomic scenarios were successfully conducted. Sorghum was grown after a feed cereal (oat), and a forage biomass of 11 t ha^{-1} and 3 t ha^{-1} were produced under rain-fed conditions in 2003 and 2005, respectively. Under irrigation conditions and taking advantage of luzerne winter dormancy, oat was sown and a silage biomass of 25 t ha^{-1} plus a hay biomass of 7.5 t ha^{-1} were harvested in two adjacent fields. The previous two agronomic sequences could be considered as two forms of 'relay cropping' where in former case sorghum did benefit of May-June rain and the stock of water left over by the prior winter crop (oat) in addition to leached nitrate. However, in the late case, oat [could be triticale (*Triticum secale*) or barley] did benefit of luzerne biologically fixed nitrogen and rain+irrigation water too.

Key words: Mediterranean climate, Conservation agriculture, Direct drilling, Site specific approach, Agronomy of opportunity,

INTRODUCTION

Cereals are strategic crops for Tunisia, a country located in the southern bank of the mediterranean where rain-fall is relatively low, irregular, sudden and intense. Rain variability within and between seasons could be observed within the same year or across years (Sakis et al., 1994). Under rain-fed conditions, food or feed cereals are mostly produced in the semi-arid zones (**Figure 1**) with a rain-fall average of 400 mm and an estimated variability of 52% over 40 years (M'Hedhbi and Chouen, 2003). In Dahmani (semi-arid zone in the North-West of Tunisia), yearly rain explained 53% of grain yield variability of bread wheat (*Triticum aestivum*), while in Tibar (sub-humid zone in the North-East of Tunisia) explained only 43% (Ben-Hammouda and Marouani, 1997). These kinds of results originated the interest of cereal researchers to study adaptation and yield stability with a special interest to large adaptation types of varieties (Boubaker et al., 1999). As rain, heat (temperature) is a major factor controlling grain yield, and heat units concept can be used in crop production to assess heat requirements of cereals for growth and development so as to fit any species in its appropriate environment (Ben-Hammouda et al., 1997).

RATIONALE

Actually, there is a growing concern toward a site specific approach for crop/cereals production and transfer of successful scenarios from one site to another is based on a cluster analysis (Grower, 1967) of an agro-ecological characterization to identify similar sites (DePauw et al, 1997). Some sites/zones are known to have early rain in the fall (September-October) before sowing cereals and late rain (June-July) while most cereal species are harvested or mature enough to be harvested. Under CD and rain-fed conditions both types of rains do not efficiently participate in biomass production as grains or straw (Ben-Hammouda et al., 2007). Consequently, a different way to cereal producers is needed and CA/DD appeared as an appropriate technology to take advantage of any drop of water whether it comes from rain or irrigation. This is the basis for agronomy of opportunity which is defined as the production of maximum biomass when the climate and the cropped species biology are favorable to do so (Ben-Hammouda et al., 2005, Ben-Hammouda et al., 2007). An agro-climatic characterization based on monthly water deficit and seasonal rain-fall curves would help to set up at least two crops a year such as a winter cereal (C-3 crop) and a summer cereal (C-4 crop), an example of an agronomic sequence for a continuing cropping system (Ben-Hammouda et al., 2006). But it is recommended to break up a cereal/cereal sequence by a short season legume to ovoid the depressive effect of an allelopathic crop such as barley (Ben-Hammouda et al., 2001) or sorghum (Sorghum bicolor L.) (Ben-Hammouda et al., 1995).

Agronomy of opportunity concept could be applied in many scenarios such as the following ones: **i)** sow a summer cover crop while waiting to harvest a mature (winter, spring) cereal, ounce receiving a late rain (40-50 mm), **ii)** for two crops/year: make out benefit of early rain (fall season) for the main crop and late rain (early summer) for the cover crop, or make benefit out of a dormant species to sow on an active one (oat/luzerne, double-purpose-barley/luzerne, triticale/luzerne), **iii)** for a potential three crops/year: make appropriate combinations out of short season variety-hybrid/species [spring peas (***Pisum sativum***), summer cereal, fall peas] and other cereals with strictly seasonal physiology (fall barley, winter wheat, spring wheat), and **iv)** use of a deeply rooted species to pump up out reached nutrients by prior superficial rooted species, and especially catch the leached nitrate.

All the above scenarios (**i, ii, iii, iv**) are possible under rain-fed conditions, but it easier to sow on a mulch/residues of a dormant species when irrigation water is available. Though the first scenario is possible using a handled-bucket for sowing, only the two crops/year scenarios were tested successfully in Tunisia with sorghum on oat mulch under rain-fed conditions (Ben-Hammouda et al., 2005 ; Ben-Hammouda et al., 2006) and oat on luzerne under irrigation conditions (**Ben-Hammouda et al., 2007**).

Agronomic scenarios in **i)** and **iv)** could be considered as cases of a 'take-over cropping' or a 'relay cropping' and the first scenario may be convenient also when the inter-crop season is too short, so a second crop would be sown on the prior one.

OBJECTIVES

When applying conventional agriculture based on CD, farmers, technicians and even agronomists deal basically with cereal production as a dependant variable of a simple regression on water whether it comes from rain or irrigation. This kind of attitude leaves little room for soil as water reservoir and physical container for both chemical and microbial activities that are closely tied with soil organic matter (OM) status. In soils with low OM rate, water of little rains either percolates quickly especially in sandy soils or gets back easily to the atmosphere giving a tiny chance to an active growing cereal crop to consume enough water. The same could be true for a cereal crop under irrigation conditions.

Applying the agronomy of opportunity concept in AC/DD is aimed to: **i)** rebuilt the soil by improving its fertility, **ii)** improve water use efficiency to produce the maximum biomass, **iii)** develop new agronomic scenarios with the use of a permanent crop residues/mulch (dry, green), and **iv)** rethink the purpose of usual cropped species in conventional agriculture.

METHODS

The AC/DD was introduced in Tunisia since 1999/00 (Ben-Hammouda et al., 2005) with an innovative approach of experimentation. Yield trials were made in the farm and field lay-outs were set in a way that they handle statistical analysis over time and space (Gomez and Gomez, 1984), but in much larger plots than the ones usually used in standard experimental research stations. Out of tilling, cultural practices applied to cropped species in CA/DD were the practices that farmers use in CD but adjusted with a nitrogen (N) compensation based on N-requirements/immobilization (Harper, 1984) of microbial population and residues decay. Nitrogen was applied at the rate of 10 kg-N t^{-1}-residues ha^{-1}, when cereal residues or weed mulch is left on the soil surface. To meet the cropped species needs, potassium, phosphorus and N were supplied according to soil analysis and target yield of the cropped species. Soils of experimental fields are alkaline (pH = 8.1) with 2%-OM and a clay dominance over sand and silt. Soil moisture profile was monitored by gravimetric technique (Hansen et al., 1979). Climatic data were collected at the nearest meteorological station.

RESULTS

1. Continuing cropping under rain-fed conditions

Sorghum was sown late spring/03 (25/May/03) in a private farm at Krib (Governorate of Siliana), just after harvesting oat for silage and one week before receiving 50 mm of rain-fall (**Photo 1**). After emergence, sorghum plants were showered three weeks later with 20 mm, then a third time with 15 mm within two weeks interval. The climate was mild and evaporative loss of water was relatively low. Consequently, sorghum vegetative growth was active (**Photo 2**) enough to let roots develop deep down and sense the moisture that was out of the prior crop (oat) reach, thus giving chance to sorghum plants to take advantage of an eventual overlapping of the former and the later soil moistures. These moisture conditions favored sorghum growth till heading stage, making an estimated forage biomass of 11 t ha^{-1} in 2003 versus only 3 t ha^{-1} in 2005. This was an opportunity for cattle to feed on fresh plant material on summer hot days (**Photo 3**). Nitrogen was applied in fraction following standard recommendations, and grazed sorghum (**Photo 4**) resumed growth after an early-September/03 rain-fall of 52 mm (**Photo 5**). At this point, farmer can make a light grazing depending on the biomass volume or use it entirely as a cover crop for preferably a legume (forage, grain).

The above scenario did not cross any farmer or agronomist mind before 99/00, when CA/DD was introduced in Tunisia for the first time. Now, continuing biomass production under rain-fed conditions is not anymore a dream but a reality for many sites known as couloirs of early (September-October) and late (May-June) rain-falls. However, lots of farmers which are not very far from the successful experimental site still burning their residues (**Photo 6** vs **Photo 7**).

2. A convenient production site to apply the agronomy of opportunity concept

The rain-fall data in Table N°1 is for Sidi-Ahmed-Essalah (Governorate of Kef) located in a semi-arid zone of the Tunisian North-West.

Table 1. Characteristics of seasonal rain-fall in Sidi-Ahmed-Essalah, for 89/90-05/06 time period.

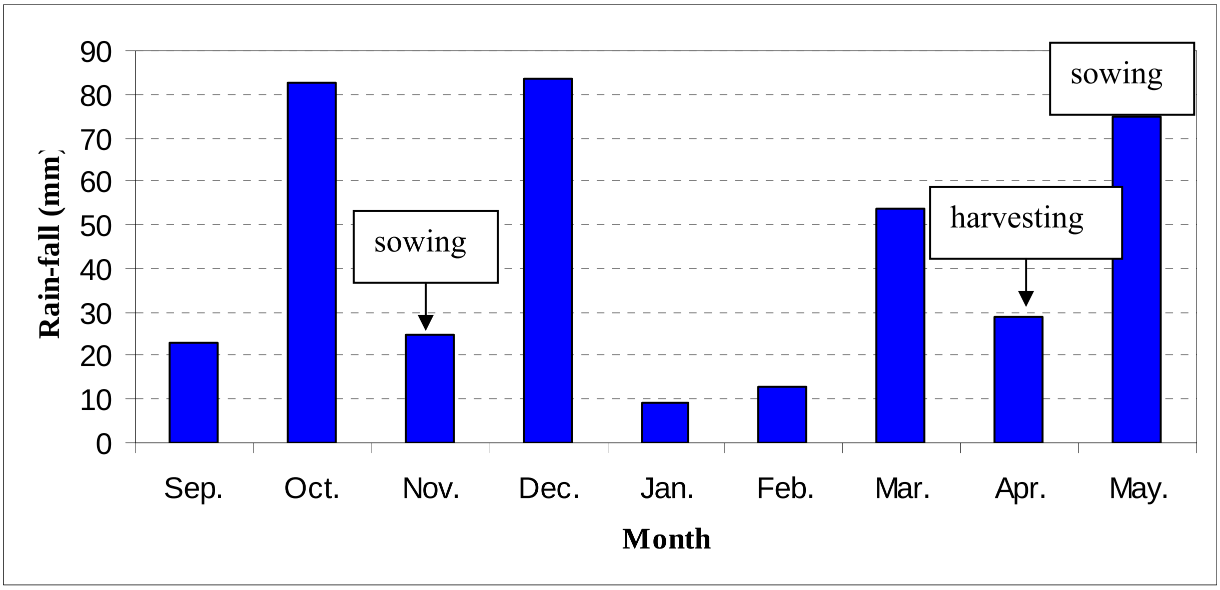
Item	Fall	Winter	Spring
Maximum	290	322	215
Minimum	41	16	35
Mean	147	129	119
CV (%)	49	67	43

Over a period of seventeen years (89/90-05/06), the total rain of the fall (September, October, November), the winter (December, January, February) and the spring (March, April, May) is on average equal to 395 mm. For this particular rain-fall distribution, farmers are not able to overpass the level of 13 q ha^{-1} under rain-fed conditions, and it is basically due to low soil OM rate, hot climate and use of physiological intermediate varieties/species of cereals. In conventional agriculture, farmers usually make one crop a year between November and June to harvest straw and grains, a kind of crop that doesn't profit much from the winter rain-fall due to severe cold. It is almost agronomy of one full year crop, and farmers still have no understanding to the benefit of a physiologically strict seasonal cereal (fall barley, winter wheat, spring wheat …). Integrating agronomy of opportunity concept in an applied formula with a cereal species of a physiological strict season would change the technical package of cereal production in such site.

3. Loss of opportunity

The site of Bou-Salem (Governorate of Gendouba) had relatively high early (October) and late (May) rains that made 26.2% and 19.9% of the total rain-fall for the 07/08 regular cereal growing season (September-May). In conventional agriculture, this kind of rain-fall is not usually productive for a November sowing of oat and March/April harvest as a silage. However in CA/DD, this scenario would allow a farmer to sow a summer cereal crop in May or use May-August period to stock water rain then sow early-September a short season (40 days) legume such as peas and ovoid a cereal/cereal sequence. The monthly rain-fall of 07/08 growing season (**Figure 2**) was suitable to make a continuing cropping under rain-fed conditions as it was successfully done in Krib site (Governorate of Siliana).

Figure 2. Monthly rain-fall in the experimental site of Bou-Salem, 07/08 growing season.



4. Continuing cropping under irrigation conditions

When milk is a major product, farmers reserve large fields for luzerne production. However, winter cold inhibited its re-growth/recovery especially after a severe cut in the mid-fall (20/October/03) and consequently it underwent dormancy. When applying conventional agriculture, farmers abandon luzerne fields till comes the spring heat. But when applying CA/DD, access to even wet luzerne field becomes possible with a special drill (direct sowing drill) and oat as a winter cereal was sown. Nitrogen requirement (50 kg ha^{-1} of ammonium nitrate 33%-N) for oat was estimated based on soil OM analysis and residual N from luzerne, therefore only one N application took place mid-November/03. From sowing (20/Octobre/02) to harvesting (15/March/03 , 29/May/03), two adjacent fields of oat/luzerne received 319 mm of rain-fall which was complemented with four irrigations totalizing 125 mm. In one field, a biomass of 25 t ha^{-1} was harvested early (15/March/03) enough to make silage and leave the space for Luzern to resume early spring growth (**Photo 8**), and the second field was left till 29/May/03 to produce 7.5 t ha-1 of hay, thus delaying luzerne re-growth. This silage and hay productions would not be possible without CA/DD.

CONCLUSION

In semi-arid zones of Tunisia, cereal producers continue to crop their land applying an horizontal technical itinerary over a wide range of agro-ecologies. Yearly rain variability is relatively high and it goes up to 40% and the same holds for seasonal and monthly rains within a year. In conventional agriculture, monoculture is the ultimate consequence that originated the break-out of soil pathogens and a sharp decline of 'cleaning' organisms. Intensive use of chemicals for high requiring cereal varieties is hazardous to both human health and environment. Soils are tilled during the summer for seed bed preparation, and therefore are exposed to heavy solar radiation which is harmful to microbial activity. Deep tillage intensifies soil oxidation which enhances OM mineralization, thus CO_2 is emitted to the atmosphere and water holding capacity of the soil is reduced. Aggregates of disturbed soils, especially in heavy slopes become fragile to sudden and intense rain-fall that characterizes the mediterranean climate and particularly the semi-arid zones of Tunisia.

To cope with above conditions of conventional agriculture, AC/DD offers opportunities to cereal producers to efficiently use every little drops of water, since the soil surface is permanently covered with crop residues/mulch (dry, green) and dynamic scenarios/sequences are conducted upon given climatic conditions within sites/zones. Cereal production could be viewed as biomass production (forage, straw, grains) with a more rational relationship between farmers and the climate. So, farmers would keep producing the same cereal species they use to crop in conventional agriculture but with flexible attitude when it comes to the choice about what species to crop. This is a site specific approach for crop production. Farmer objective (grains, grazing, cover crop, water storage for a subsequent crop, rebuilt of soil fertility) may change according to rain-fall regime. So, there are no static rotations as is thought in conventional agriculture.

The most important opportunity concerns scientists/researchers, regarding an urgent need to accompany the spreading of CA/DD with basic research on different themes. For example, weeds flora is inversed in comparison to conventional agriculture and the field of phyto-pharmacy has to deal with new population dynamics. It is time also to develop new agronomic terms for AC/DD and ovoid the use of no-till/zero-till which carries over the sound of tillage while being less explicit about the use of a permanent mulching. When a farmer decide to move from conventional agriculture to CA/DD, he has to de-compact (clay pan, hard pan) and drain the soil if necessary, therefore a research is needed to develop cereal varieties with pivot type of rooting systems.

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Figure 1. Bio-climatic map of Tunisia.

Photo 1


Photo 2


Photo 3

Photo 4

Photo 5

Photo 6

Photo 7

PHOTOS TITLES

Photo 1. Sowing sorghum on 25/May/03, after harvesting oat for silage.

Photo 2. Active growth of sorghum, June/03.

Photo 3. Cattle grazing fresh sorghum on a summer hot weather, July-August/03.

Photo 4. Sorghum stands (late-August/03), after being grazed by cattle.

Photo 5. Sorghum re-growth after receiving an early rain in the fall (early-Setember/03).

Photo 6. A summer sorghum biomass in Al-Alya/Krib, where agronomy of opportunity concept was successfully applied.

Photo 7. In a twenty kilometers cross site (Hammam-Byadha/Krib) from Al-Alya/Krib, farmers still burn dry residues/mulch.

Photo 8. Growing oat for silage and hay on dormant Luzerne, and it could be barley or triticale instead of oat.