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# Wheat response to nitrogen fertilization and sunflower residues soil incorporation in a semi-arid field conditions study of Meknes Region-Morocco

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***Abstract:*** *In a field study in the region of Meknes, Morocco, two experiments were conducted. The first was carried out to investigate wheat's response to nitrogen supply (0.80 and 140 kg N/ha) and to soil incorporation of sunflower residues (0 and 5t/ha). The second field experiment was carried out to study wheat response to soil incorporation by increasing sunflower residues rates (0,5 and 10 t residues/ha). In the first experiment, nitrogen fertilization and residue incorporation only slightly affected wheat yield. This was related to drought which could have reduced wheat nitrogen needs and decreased the importance of immobilization. The results of the second experiment showed that wheat yield was depressed as a result of residue incorporation into soil but was not affected by increasing residues rate. It was concluded from this study that residues incorporation into soil can immobilize soil nitrogen and depresses wheat production. This effect is more important in humid conditions.*
***Keywords****: Immobilization, nitrogen fertilization, residues incorporation, soil, sunflower residues*

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## I. Introduction

Cereals are the main crop in Morocco, occupying about 80% of the total agricultural area. The Meknes plateau (Morocco) is an important source of cereal production on a national scale. In this region, wheat is generally grown in a biennial rotation with legumes and certain spring crops including sunflower. Sunflower is the main annual oilseed crop in Morocco (Achbani & Tourvieille, 1993). Little research has been done on the sunflower-wheat crop rotation. Nevertheless, surveys of farmers in the region of Meknes have shown that when wheat is grown after sunflower, a significant yield decrease was observed compared to wheat grown after other crops. Although the N requirements of sunflower are less important compared to winter cereals, this element is the most absorbed nutrient in large quantities by the sunflower crop (GRDC, 2018), an important part of which comes from soil (Lecomte & Nolot, 2011). Knowing that farmers apply modest amounts of nitrogen fertilizer to sunflower, small quantities of residual nitrogen would remain available for subsequent crops.

In addition, a significant portion of nutrients exported by sunflower can be returned by residues when buried in the soil (Babu& al., 2014; Rodriguez-Lizana& al., 2010). Other benefits can be associated with their incorporation into the soil. Indeed, residues have a considerable role in building soil organic matter (Havlin& al., 1990; Lal, 2005; Larson & al., 1972; Rathod& al., 2019), recycling of mineral elements (Parr & Papendick, 1978; Power & Legg, 1978; Smith & Elliott, 1990; Zhang & al., 2008) and can also improve soil physical properties and protect it from degradation (Carlesso& al., 2019; Hayes &Kimberlin, 1978; Skidmore &Siddoway, 1978; Xing Wang & al., 2019). However, nitrogen content of sunflower residues is low; burying them in the soil could immobilize mineral nitrogen and create a deficiency for the wheat succeeding crop. This phenomenon could be accentuated in areas of concentrated residue. Indeed, the distribution of residues in the field is not uniform; they are more abundant in the strips spread by the combine harvester. Plowing can also cause a non-uniform distribution of residues.

The objective of the present work is to study the effect of nitrogen fertilization and soil incorporation of sunflower residues on wheat yield succeeding sunflower under field semi-arid conditions of Meknes region.

## II.Material and Methods:

***Climatic and edaphic conditions of the study site.***The field study was conducted in the region of "Ain Orma", 15 km from the city of Meknes (North of Morocco). Its climate is essentially semi-arid Mediterranean with temperate winters; the average annual rainfall is 526 mm(Corbeels& al., 1998). The year of the experiment was particularly dry, the rainfall received during the agricultural season was 320 mm. The study took place in a plot with a previous sunflower crop. The physical characteristics of the soil are shown in Table 1. The mineral nitrogen of the soil before seedlings was 24mg/kg of soil. Other chemical characteristics are represented in Table 2.

**Table 1:** Particle size and total limestone analysis (mg/kg soil) of sunflower previous crop and pea previous crop soils fromthe horizon 0-20 cm.

| | Clay | Fine silt | Coarse silt | Fine sand | Coarse sand | Total limestone |
|---|---|---|---|---|---|---|
| **Sunflower previous crop** | 57.34 | 14.26 | 17.31 | 5.00 | 6.08 | 428 |
| **Pea previous crop** | 53.41 | 26.29 | 9.60 | 6.29 | 3.76 | 231 |

**Table 2:** Soil chemical analysis of sunflower previous crop and pea previous crop soils from the horizon 0-20 cm.

| | pH ($H_2O$) | pH (KCl) | %N | %C | %MO | $P_2O_5$ (ppm) | KCl (ppm) | Mg (meq%) | P.F. (4.2) |
|---|---|---|---|---|---|---|---|---|---|
| **Sunflower** | 7.9 | 6.8 | 0.14 | 1.48 | 2.55 | 17 | 324 | 7.75 | 22 |
| **Pea** | 7.9 | 6.9 | 0.15 | 1.79 | 3.09 | 20 | 310 | 11.25 | 20 |

***Experiment I.*** This experiment was undertaken to study the effect of soil incorporation by sunflower residues and the impact of nitrogen fertilizer on wheat growth and yield in a sunflower wheat rotation. The experimental design adopted was completely randomized with five replications. Two factors were studied. Residue treatment; $R_0$: Control sample without residue, $R_1$: 1125 g residue/plot (equivalent to 5 t/ha). Nitrogen treatment: Three doses of nitrogen were chosen; $N_0$: Control 0 g N/plot. $N_1$: 18 g N/plot (80 kg N/ha). $N_2$: 31.5 g N/plot (140 kg N/ha). For $N_1$ and $N_2$, 4.5 g N/plot was applied as a basic fertilizer.
The study was carried out in a plot of 200 m² in area where sunflower was croppedin the preceding year. After harvesting sunflower, residues were removed from the field. The plot was subdivided into 30 plots of (1.5 x 1.5) m² area, spaced by a 1m border. Forty days before sowing, sunflower residues consisting of a mixture of stems, roots, and flower heads were ground into small pieces of about 1 $cm^2$, and incorporated into the surface layer of the soil (0-10 cm). The %N of these residues was 0.4. Half of the plots were incorporated, and the other half were not. Basic fertilization was applied in the form of NPK for the nitrogen treatments and PK for the non-nitrogen treatments. Nitrogen was applied as $(NH_4)_2SO_4$ at 20 kg N/ha. Phosphorus and potassium were applied before sowing at 60 kg P/ha as $K_2SO_4$ and 80 kg k/ha as KCI. Wheat (*Triticumaestivum, var. El Kenz*) was sown at the end of November, on 9 rows at a rate of 40.5 g/plot, equivalent to 180 kg/ha. At tillering stage, cover nitrogen was applied in the form of $(NH_4)_2SO_4$; 13.5 g N/plot (60 kg N/ha) for $N_1$ and 27 g N/plot (120 kg N/ha) for $N_2$. At maturity, wheat was cut; the sampling concerned the central square of (0.5x0.5) m² of each elementary plot.
***Experiment II.*** This trial was conducted to examine the effect of soil incorporation of increasing rates of sunflower residueson wheat yield. It was conducted in a 100 m² plot where sunflower was grown in the previous year. Soft wheat (*Triticumaestivum, var. El Kenz*) was sown in 12 plots of 1m² area spaced by 1m. The physicochemical characteristics of the soil are represented in Tables 1 and 2. The experimental design adopted was completely randomized with 4 replications, only one factor was studied, the dose of residue applied to the soil. Three doses were chosen; $R_0$: Control without residue. $R_1$: 500g of residues/m² (5 tons/ha). $R_2$: 1000g/m² (10 tons/ha). The $R_1$ dose (5t/ha) corresponds to the average dose of residues returned to the soil under field conditions. Three months before sowing, after having eliminated the sunflower residues of the previous season, the sunflower residues were incorporated in the superficial horizon 0-10 cm of the soil. They consisted of a mixture of leaves, stems, roots and flower heads, cut into small 1 $cm^2$ pieces. Their %N was 0.54. The starter fertilization, seeding and harvesting of the plots were similar to those of the first field experiment. A single dose of nitrogen equivalent to 80 kg/ha was applied in the form of $(NH_4)_2 SO_4$.
***Measurements made***. Wheat samples were oven-dried at 80°C for 48 hours. Shoot dry weight was measured. After threshing the ears, grain and straw dry weights were measured. A fraction of these two parts was finely ground (0.5 mm) in order to analyze their respective %N and total nitrogen by the Kjeldahl method (Nelson & Sommers, 1973). An analysis of variance was performed using the completely randomized design with 5 replications for experiment I and 4 replications for experiment II. When the effect of a factor was significant, at the 0.05 probability level, the means were compared by the smallest significant difference (LSD).

## III. Resultats

***Experiment I.***Grain yield and straw dry weight were significantly affected by the nitrogen factor. Residue input and the interaction of the nitrogen factor and the residue factor showed no significant effect (Table3). The positive response of wheat to N was manifested in improved grain and straw yields (Table 3). Nevertheless, it is important to mention that the contribution of N to improve wheat productivity was small. Indeed, even with the application of the $N_1$ dose (80kgN/ha), the increase in grain dry weight compared to the $N_0$ control dose without nitrogen was not significant. The $N_2$ dose (140 kg/ha) gave a slight improvement in grain yield compared to the no-nitrogen control dose both in the presence and absence of residues. Regarding straw dry weight (Table 3), the $N_1$ dose of nitrogen caused a slight increase compared to $N_0$. However, this improvement was not significant in the treatment with residues. From 80 kg N/ha onwards, wheat was unresponsive to N supply.
As with dry weight, total grain nitrogen and total straw nitrogen were reduced by the presence of sunflower residues. The effect of residues was highly significant on total straw nitrogen. Fertilizer nitrogen input induced an increase in total plant nitrogen level (Table 3). With the $N_1$ dose (80 kg N/ha), it tended to be maximal. In fact, except for the total straw nitrogen of the residue treatment, the increase in total grain and straw nitrogen was not significant beyond the 80 kg N/ha dose.

**Table 3:**Grain yield (G.Y), straw yield (S.Y.), Grain nitrogen (G.N.) and straw nitrogen (S.N.) of wheat with nitrogen fertilizer doses$N_0$: Control 0 g N/plot. $N_1$: 18 g N/plot (80 kg N/ha). $N_2$: 31.5 g N/plot (140 kg N/ha), and with incorporation of sunflower residues doses with %N 0.4; $R_0$: 0; $R_1$: 5t residues per ha (LSD: least significant difference, NS: not significant)

| | **G.Y. Qs/ha** | | | **S.Y. Qs/ha** | | | **G.N. kg/ha** | | | **S.N. kg/ha** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $R_0$ | $R_1$ | LSD (0.05) | $R_0$ | $R_1$ | LSD (0.05) | $R_0$ | $R_1$ | LSD (0.05) | $R_0$ | $R_1$ | LSD (0.05) |
| $\mathbf{N_0}$ | 14.78 | 13.86 | NS | 19.84 | 19.16 | NS | 24.61 | 23.48 | NS | 07.93 | 06.24 | NS |
| $\mathbf{N_1}$ | 19.08 | 18.36 | NS | 28.32 | 25.26 | NS | 40.37 | 39.29 | NS | 13.56 | 08.94 | 4.56 |
| $\mathbf{N_2}$ | 21.10 | 18.94 | NS | 29.21 | 26.30 | NS | 47.15 | 43.44 | NS | 16.53 | 14.10 | NS |
| **LSD (0.05)** | 4.83 | NS | | 6.00 | 6.13 | | 12.74 | 16.44 | | 04.86 | 03.28 | |

***Experiment II.*** Residue application significantly influenced total straw nitrogen and very significantly straw and grain dry weight and total grain nitrogen. For these four parameters, the effect of residues was manifested by a significant drop in yield in treatments $R_1$ (5 tons of residues/ha) and $R_2$ (10 tons of residues/m²) compared to treatment $R_0$. On the other hand, the increase in residue rates from $R_1$ to $R_2$ did not have a significant effect on the different yield components. The yield decrease caused by the addition of residues was 37% for grain and straw dry weight, 23 and 37% for total nitrogen in straw and grain respectively (Table 4).

**Table 4:** Comparison of grain yield (GY), straw yield (SY), grainN (GN), straw N(SN), grain %N(%GN) and straw %N(%SN) of wheat planted after sunflower crop, with the addition of different nitrogen doses $N_0$: Control 0 g N/plot. $N_1$: 18 g N/plot (80 kg N/ha). $N_2$: 31.5 g N/plot (140 kg N/ha).(LSD: least significant difference, NS: not significant).

| | **GY Qs/ha** | **SY Qs/ha** | **GNkg/ha** | **SNkg/ha** | **%GN** | **%SN** |
|---|---|---|---|---|---|---|
| $\mathbf{R_0}$ | 29.41 | 36.69 | 71.70 | 13.80 | 2.45 | 0.37 |
| $\mathbf{R_1}$ | 18.42 | 22.93 | 33.90 | 10.20 | 2.06 | 0.45 |
| $\mathbf{R_2}$ | 18.59 | 22.87 | 33.40 | 10.60 | 1.81 | 0.47 |
| **LSD (0.05)** | 5.95 | 7.15 | 12.10 | 2.77 | 0.16 | 0.07 |

## IV. Discussion

From the results of Experiment I, a poor response of wheat to nitrogen supply due to drought can be observed. Similar results have been reported in several other studies (Black, 1966; Fowler, 1989). According to(Ryan & al., 2009), lack of water under Mediterranean conditions limits crop response to nitrogen. In a 21-year comparative study of zero tillage and conventional tillage in Spain (Fernández& al., 2007), in general, no difference in yield in a wheat-sunflower-legume rotation was noted, although the soils were enriched with nutrients because the limiting factor was a lack of water and not nutrients. Regarding the effect of residues on wheat, we found that wheat yield was slightly decreased in the presence of residues. These results are comparable to those found in other studies; in a region with low annual rainfall (240 mm), Harris (1963) reported that incorporation of wheat straw into the soil decreased soil nitrates but had no significant effect on wheat grain yield. These results were explained by the drought that made the soil mineral nitrogen in excess of the low requirements of wheat. Under greenhouse conditions, Hdoudouch (1994) found that sunflower residues did not affect wheat production under dry conditions and decreased it under wetter conditions. In our experiment, the tendency of residues to affect nitrogen uptake and dry matter of wheat could be explained by immobilization of mineral nitrogen by microorganisms that degrade the residues. On the other hand, the low influence of these residues on wheat production could be related to a slow degradation of the residues caused by the lack of water (Scott & al., 1986), thus a low amount of immobilized nitrogen. This can also be attributed to a modest demand of wheat for nitrogen caused by soil water deficit. In the latter case, although immobilization occurred, it would not have created a nitrogen deficit for the plant.

In the second experiment, the decrease in the total nitrogen content of the grains in the treatments amended with sunflower residues indicates a decrease in nitrogen availability in the soil. This would be related to the immobilization of nitrogen in the presence of residues. The decrease in soil N availability would also have depressed grain and straw dry matter.

Nitrogen immobilization by low-percentage nitrogen residues under field conditions has been demonstrated by several authors(Powlson& al., 1985; Christensen, 1986). It causes a reduction in nitrogen uptake and a drop in crop yields (Wang & al., 2018)

These results appear to be contradictory to those found in Experiment I, where application of the same residue rate and fertilizer rate (80 kg/ha) did not result in a significant decrease in yield compared to the non-residue control sample. These differences in wheat response to soil incorporation of sunflower residues could be attributed to the timing of residues incorporation. Indeed, in this experiment residues were incorporated into the soil at the beginning of September; 50 days before the incorporation of the residues in Experiment I, and they were able to benefit from 50 mm of rainfall received during this period, this rainfall would have allowed for earlier decomposition of the residues and therefore immobilization of nitrogen. In Experiment I, residue burial was done under dry conditions, which would have decreased immobilization. These results highlight the role of water in the decomposition of residues and in the response of wheat to their presence in the soil. On the other hand, the residues used in Experiment II are probably less concentrated in lignified compounds because they contain 21% sunflower leaves, which were not included in the composition of the residues in trial I. Several authorshave shown that residue decomposition is generally negatively related to residue lignin content (Fox & al., 1990; Hofmann, 2009; Muller & al., 1988; Palm & Sanchez, 1991;Yanni & al., 2011). The rapid decomposition of leaves in Experiment II would thus have allowed for nitrogen immobilization in the early stages of residue decomposition.

Despite the fact that residue incorporation resulted in a decrease in dry matter and N uptake by wheat, Table 4 shows that straw N concentration was significantly improved by residue addition. This result could be attributed to a delay in the maturity of wheat in the residue treatments, which would have caused a delay in the translocation of N to the grain. Indeed, the grains of the treatment without residues were more concentrated in nitrogen than the grains of the treatments $R_1$ and $R_2$. In this regard, Anderson & Russell (1964) and Wilhelen& al. (1989) reported that the presence of residues in the soil was accompanied by a decrease in soil temperature that caused a delay in wheat emergence, and thus caused a delay in maturity. In contrast, Jessop & Stewart (1983) attributed the delay in wheat germination to a phytotoxic effect of residues, they also found that this effect had a weak interaction with soil temperature. In our experiment, soil temperature did not appear to affect wheat development. The allelopathic effect of sunflower residues has been reported in several studies (Babu& al. 2014).

In conclusion, the results of Experiment I revealed that the response of wheat to increasing nitrogen rates and soil burial of sunflower residues was low. This was attributed to drought conditions that would have decreased the nitrogen requirements of wheat and reduced nitrogen immobilization in the presence of residues. In contrast, in the second experiment, the low wheat production in the presence of sunflower residues may be related to the early burial of the residues and their low content of lignified compounds.

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