Demonstrating fertilizer response and Hessian fly resistance with wheat in Morocco

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ABSTRACT

Hessian fly (*Mayetiola destructor* Say) is a major cereal pest in Morocco and other semiarid areas of the North Africa–West Asia region. Research has focused on mitigating its effects, largely by introduction of resistant or tolerant varieties. One such bread wheat (*Triticum aestivum* L.) variety, 'Saada' (SD8036), was compared with established bread, i.e., 'Nesma' and durum, i.e., 'Cocorit' (*T. turgidum* L.) wheat in a research-demonstration trial using fertilizers (100 kg N and 36 kg P ha^{-1}) and chemical control of weeds, fungi, and Hessian fly. The trial site, on a Calcixeroll, was near a major highway for maximum visibility. The impact of Hessian fly was apparent in the early growth stages. However, this was not reflected in final yield data. Without N, Saada was similar to Nesma and Cocorit in grain yield, but higher in straw yield. Grain yield response to added N was lower with Saada, though the straw yield response was high. Grain protein for Saada tended to be lower than the other varieties. As such parameters tend to be environment-specific, and the severity of Hessian fly damage varies with season, a comprehensive program of testing Saada at multiple locations appears to be warranted.

In recent years there has been a growing and vocal concern in developed nations for the plight of developing areas of the world, which are largely characterized by high population growth rates and decreasing per capita food production. Efforts to promote "agricultural development" are based on a spectrum of motives, ranging from humanitarian to political and economic. Although much has been written about technology transfer, a common theme focuses on the need for a multidisciplinary approach that considers biological as well as social aspects (Alvarez, 1982). The use of field demonstration plots is a well-accepted and proven extension tool (Daigger et al., 1975; Nafziger, 1984; Kittrell, 1974). Such plots usually attempt to highlight visual differences between crop varieties and the effects of fertilizer and other imputs alone or in combination. Frequently, a package of improved practices is compared with low-input or traditional management by the farmer. Initially, on-farm field trials tend to be managed by the researcher. As the benefit of the proposed improved practice becomes clearer, the subsequent trials may be completely handled by the farmer.

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Demonstration trials have an even greater potential for promoting technology transfer in developing countries. Land holdings are mainly small and fragmented in developing countries compared with developed countries. Failure to focus on the unique circumstances of such farmers has often hampered development efforts (Brams, 1980). Rhoades (1984) recognized the importance of specific sociocultural perspectives and presented several guidelines for scientists to consider before initiating field trials. Nevertheless, despite such caution, trials involving fertilizer or lime, where both are clearly shown to be deficient, can promote rapid adoption (Beatty et al., 1972). Given the precarious nature of crop production in semiarid zones, the need for enhanced output through implementation of new technology is even more acute than in more favorable climatic zones.

With a high population growth rate and decreasing self-sufficiency in food production, Morocco typifies many countries in the North Africa–West Asia region (Shroyer et al., 1990). However, a major agricultural development effort is underway in its mainly cereal-growing, low-rainfall zone; this involves the USAID-funded Dryland Agricultural Project of the Mid-America International Agricultural Consortium (MIAC) in collaboration with the host country's Institut National de la Recherche Agronomique (INRA). The project has established the Aridoculture Center in Settat along with a research program dealing with nearly all phases of the region's farming systems. The project also supports advanced degree training of national scientists to staff the center. Since its inception in 1980, field research has focused on promoting fertilizer use (Abdel Monem et al., 1988) and combating the implacable insect pest of cereals in the region, Hessian fly (*Mayetiola destructor* Say). Surveys in Morocco (Hatchett et al., 1984) and the North Africa–Middle East region (Miller, 1987) point to substantial yield losses most years due to this pest.

Because cultural practices do little to control Hessian fly in cereals, except perhaps through timely planting or chemical control, which has technical difficulties and is costly, breeding of resistant varieties is the only feasible approach to abate its effects (El Bouhssini et al., 1986). Selection efforts have identified one resistsant variety that may be useful in Morocco [Saada (SD8036)], which was developed in South Dakota, USA. Saada was released in the national variety catalogue in 1988. Initial concerns were to demonstrate its potential to farmers and simultaneously show the effect of fertilizer use. In this semiarid area, many farmers do not use fertilizer and are unaware of its benefits. As more efficient use can be made of labor and material resources by combining cultivar testing with soil fertility trials (Follett et al., 1987), the demonstration-research trial described in this article combined elements of cultivar testing with fertilizer response. It was conducted at a site previously used for soil test calibration studies (Abdel Monem et al., 1988).

MATERIALS AND METHODS

The site chosen for this researcher-managed trial was on a farmer's field near Sidi El Aydi Agricultural Experiment Station and adjacent to the main Marrakesh-Casablanca highway. The site was readily visible from the road and accessible by vehicles to facilitate demonstration; a 30-m wide border was kept uncropped and mowed when necessary in front of the trial block to accommodate field-day participants and other groups. The soil at the site, a Calcixeroll of medium depth (65 cm), is one of the dominant soils in the Berrechid plain area of the Chaouia region (Stitou, 1985). The land was leased from a farmer for the year on a no-fee basis. However, the farmer was paid as a "guardian" to provide continuous supervision of the area. The area was surrounded by a rope attached to metal bars to prevent theft or animal damage. He or a family member was at the site on a 24-h basis, using a project-provided tent for shelter and rest. He knew of the trial's purpose to explain it to interested neighbors and keep a record of visits to the site.

The previous year's crop was corn (*Zea mays* L.). Prior to cultivation with an offset disc (known locally as a "covercrop") in October 1987, the soil was sampled with a Giddings probe and analyzed; 12 separate borings were made in the plot area. Average soil pH was about 8.2. With increasing depth (i.e., 0- to 20-, 20- to 40-, and 40- to 60-cm segments), decreases occurred in organic matter (3.4, 2.4, and 1.7%), but values were somewhat inconsistent for NO_3 (5.5, 3.9, and 11.0 mg/kg) and $NaHCO_3$-P (6.9, 4.1, and 5.0 mg/kg). However, the $CaCO_3$ content increased with depth (22.6, 40.1, and 47.7%, respectively). Texture was uniform with depth, with sand, silt, and clay being 26, 20, and 54%, respectively.

The trial involved three fall-planting spring wheat varieties: Nesma, the principal bread wheat in Morocco; Cocorit, a prominent durum wheat; and a newly introduced wheat, Saada, which is resistant to the Hessian fly. This latter variety was developed in South Dakota State University and has undergone preliminary testing in Morocco. The trial was laid out in a split-plot design with varieties as main plots, and with treatment vs. no-treatment as subplots. Plots were 40 m long and 4.5 m wide; they consisted of 18 rows 25 cm apart or three runs of the planter. All treatments were duplicated.

The treatments were a control, with no fertilizer except P, similar to local farmer practice, and one with fertilizer and chemical control of Hessian fly. The latter consisted of 100 kg N/ha broadcast as ammonium sulfate and carbofuran (Furadan) (2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate), applied at 1.1 kg a.i./ha with the susceptible varieties, Nesma and Cocorit, to control Hessian fly. Phosphorus was not included as a variable because a response was unlikely; the $NaHCO_3$-P level was marginal relative to the critical value range of 5 to 7 mg/kg (Abdel Monem et al., 1988). Keeping the trial simple with limited plots was another consideration. However, P was applied at 35 kg/ha as triple superphosphate drilled with the seed as a "blanket" treatment to all plots. Following planting at 80 kg seed/ha on 15 Nov. 1987 and subsequent emergence, weeds on all plots were controlled by Cetrol-H, while Tilt (1-[2-(2,4-dichlorophenyl)4-propyl-1,3-dioxolan-2-ylmethyl]-1*H*-1,2,4-triazole) fungicide was applied to control foliar diseases.

Whole-plant samples were taken from 1-m sections of central rows at tillering (12 Feb. 1988) and at anthesis (9 May 1988). These samples were dried in an oven at 70 °C for 48 h, and subsequently ground and analyzed for N using the Kjeldahl procedure to estimate N uptake. At harvest, two 5-m rows from each plot were cut at ground level by hand using a sickle. The dried, bagged material was weighed and subsequently threshed. Following cleaning, grain samples were weighed and analyzed for N to calculate crude protein (i.e., N% × 6.25). All data were analyzed statistically using analysis of variance with LSD values to differentiate significant treatment effects.

Because the purpose of the trial was to demonstrate a new variety and an improved package of practices, the site was sign-posted with large lettering. Experimental details were clearly shown along with the responsible institutions—the National Institute for Agronomic Research (INRA) in collaboration with the Mid-America International Agricultural Consortium (MIAC) at the newly established Aridoculture Center in nearby Settat. The season was favorable for growth, with rainfall (470 mm) above average (300 mm/yr) and well-distributed. Treatment differences were readily apparent from emergence. The response of the taller-strawed variety, Saada, was obvious from the road. During the season, several organized groups—researchers, extension personnel, farmers, government officials and administrators—visited the site. Unscheduled visits were made by many interested people passing on the highway.

RESULTS

Differences in growth due to insect resistance were already apparent by the tillering stage when plant material was sampled for N analysis. Similarly, differences between control and treated (i.e., fertilized) plots were visually striking. The N concentration of the plant from the untreated plots was relatively uniform at 3.25 to 3.30%. The corresponding values for the treated plots ranged from 3.40 to 3.60%. When differences in dry matter were considered for total N uptake (Fig. 1), it was clear that all treated plots were the same, whereas N uptake by Saada was about twice that of the two varieties susceptible to Hessian fly, on the untreated plots.

Random observations revealed a mild fly infestation in plots of Nesma and Cocorit, which were not treated with Furadan or N. Although Hessian fly usually occurs in two or three stages that coincide with separate genera-

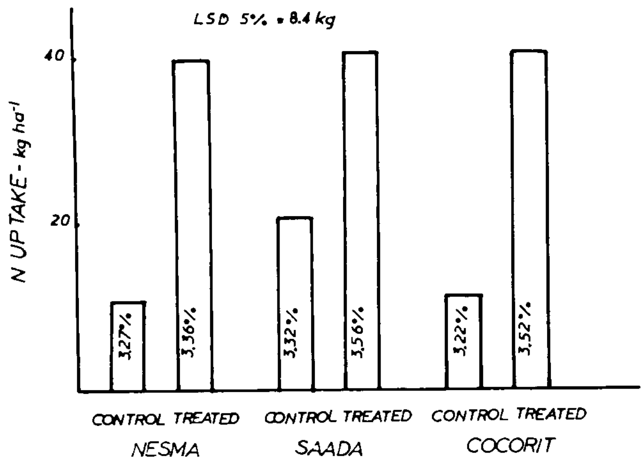

Fig. 1. Mean N concentration (within columns) and total N uptake of wheat sampled at tillering.

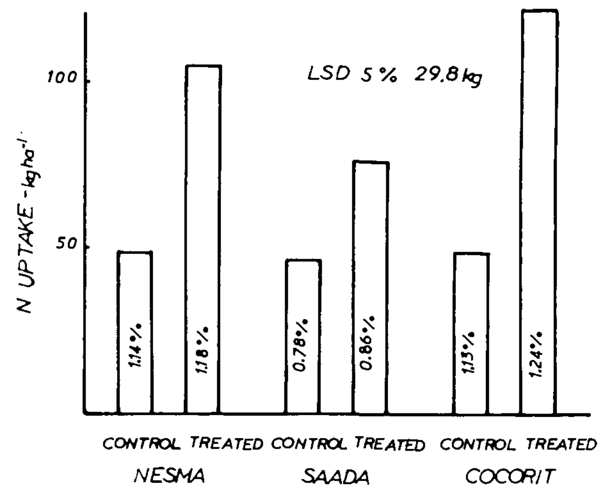

Fig. 2. Mean N concentration (within columns) and total N uptake of wheat sampled at anthesis.

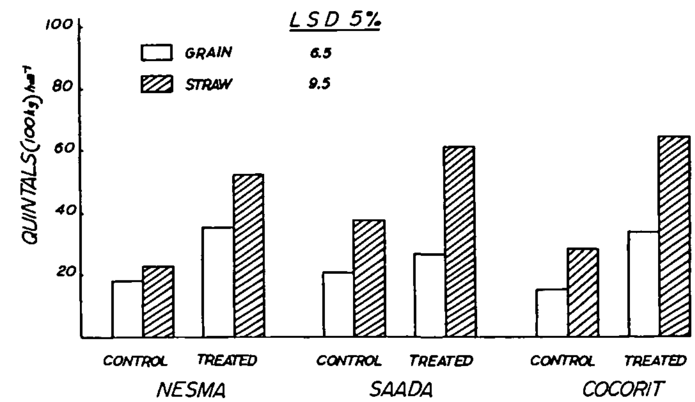

Fig. 3. Mean grain and straw yields following harvest.

tions of larvae throughout the growing period, there was little evidence of later attacks in this trial. Consequently, when N uptake at anthesis and final grain and straw yield were examined, a different picture from the early growth stage was evident.

The N analysis and uptake at anthesis revealed interesting differences between the varieties. Although there was a small difference in plant N concentration between Nesma and Cocorit, treated plots were slightly higher and both were markedly higher than Saada, i.e., 1.13 and 1.24% vs. 0.78 to 0.86% (Fig. 2). These differences were clearly reflected in N uptake data. No significant differences were evident between the three varieties without treatment. But both Nesma and Cocorit had higher N uptake than Saada when treated.

The early growth superiority of Saada was not reflected in increased grain yield in the untreated plots. Although Saada had a slightly higher yield than either Nesma or Cocorit, differences were not significant (Fig. 3). The straw yield of this taller variety, however, was significantly higher than untreated Cocorit or Nesma. Responses of the varieties to the treatment package, i.e., N and Furadan (except with Saada), were significant for grain and straw. This time, however, grain yield of Saada was less than Nesma or Cocorit; yield increases over the untreated controls for Nesma, Cocorit, and Saada were 200, 220, and 26%, respectively. In terms of straw yield, Saada and Cocorit were somewhat higher than Nesma.

Despite the N concentration differences in the plant material, no marked differences in grain protein were apparent. For Nesma, Saada, and Cocorit, the respective values were 9.9, 8.6, and 8.9% for the untreated plots, and 10, 9.4, and 10.1% for the treated plots.

DISCUSSION

This combination research-demonstration on-farm trial showed positive visual aspects, and also revealed through data analysis the need for further field research. The obvious superiority of Saada in terms of early growth and stand height caught the attention of the visitors who viewed the trial. Had the initial attack of the first generation of Hessian fly been more severe, or if subsequent generations of larvae occurred, differences between Saada and the two susceptible cultivars (Nesma and Cocorit) would no doubt have been accentuated. To the south, in the drier Abda region, Hessian fly devastated stands of Nesma, particularly when planted late, but had no effect on Saada (Keith, 1988).

The immediate impact of the trial was with researchers; the research interest generated in the potential of Hessian fly-resistant wheat resulted in a workshop at the Aridoculture Center on Saada wheat. Subsequently, on-farm trials with Saada and other varieties were planned for all diverse agro-ecological zones in the semiarid project area; these encompassed varying planting dates, population density through different seeding rates, and fertilizer—especially N. Because it has a smaller, reddish seed in contrast to the established varieties, a socio-economic study was planned to evaluate farmer acceptance of the new variety.

The trial also generated interest with extension personnel; plans were made to incorporate Saada into the network of trials by the extension service or Centres de

Travaux (CT). At farm level, interest was expressed in demand for seeds of the new variety. As straw is important for animal feed in this region of Morocco, varieties with high straw yields may be more attractive, even if grain yields are not better than established varieties.

Despite the potential of Saada, the apparent poor response to N and low protein of the grain need to be addressed. Because these data were generated from only one site in 1 yr, further testing under different soil types and with varying rainfall is required before definitive statements can be made. Indeed, given the annual variability in Hessian fly attack, comparisons must be made over a few years. Also, Saada's response to N can be fully evaluated only when a range of application rates is used rather than the single rate that was used in this study. Similarly, time of N application is a factor to be considered in relation to the stage of insect attack and its implication for grain protein. Although the soil type in the trial area was adequate in available P (Abdel Monem et al., 1989), future work must consider Saada's response to P.

Despite periodic, significant advances in researchers' attempts to move crop yields off plateaus set by environmental and management factors, the prospect of future yield increases will depend largely on plant breeders. Pest resistance must be incorporated with genetic yield potential. Currently, efforts are underway to combine more high-yielding genes with Hessian fly resistance. Furadan can be used successfully by researchers to combat Hessian fly, but numerous factors dictate that it probably won't be used at the farmer level (e.g., toxicity, high cost, and the requirement of a grain drill in an area where hand broadcasting of grain is dominant). The yield potential of other varieties that are susceptible to Hessian fly, however, can only be demonstrated by chemical control of the pest. Another desirable feature of the Hessian fly-resistant Saada wheat is that it carries genes for resistance to common cereal diseases, rust (*Puccinia* sp.) and Septoria diseases.

The marked yield increase due to N in this trial points to the crucial role of commercial fertilizers in enhancing cereal output in Morocco. Fertilizer use has increased steadily in Morocco (Mouline, 1979), but such responses as observed here and the widespread appearance of N deficiency during the growing season, particularly in the low rainfall area, underline the need to promote increased fertilizer use by farmers.

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