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# Enhancing farm profitability by growing wheat for chapatti quality markets in Haryana, India

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**In field experiments in six districts of Haryana, best practice management (including zero tillage and 3-way split application of N-fertiliser) provided small (2%) improvements in grain yield when compared with local farmer practice. This best practice management also gave consistent improvement in chapatti quality as measured by grain hardness (11.4%) and chapatti score (3.2%). Where a 'shot-gun' mix of micronutrients and sulphur was included with farmer practice treatment, or with best practice treatment, grain yield was increased by about 3% and there were further improvements in quality. Net returns were calculated for wheat production, the large cost saving associated with not undertaking the 4 cultivations used in local farmer practice, the best practice treatment was always the most profitable (by 9%), and even if no yield improvement was assumed this treatment would still be 6.7% more profitable. Even though it had a 30 to 40% yield penalty, the most profitable practice involved using variety C-306. This is an old wheat variety recognised as the standard for chapatti quality, and C-306 gets at least twice the market value of wheat sold at prices set as a minimum support price. High yields of wheat and its availability is an on-going priority for India, particularly for maintaining food security for the large population. Therefore, any wholesale change in production that moves farmers away from optimizing total grain production is untenable. However, 16 to 20% of farmers and consumers already have some direct marketing/purchasing of the wheat harvest via local markets, and these often involve quality considerations.**

**Key words:** Chapatti quality, profitability, wheat marketing.

## INTRODUCTION

Wheat and other crops are grown sequentially in an irrigated, double cropping pattern in Haryana and Punjab states (North-West India) (Coventry et al., 2011c) on about 5.7 M ha area. Among the various cropping rotations, rice-wheat is a major cropping system for sustaining food security in the region and these states play a dominant role in building grain buffers for the whole country. There are millions of farmers and agricultural workers dependent on this system for their livelihoods. Profitability is the key motivation for these

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farmers and their aim has been to harvest maximum yields. The majority of the wheat grown is consumed as traditional Indian flat bread (chapatti). Chapatti quality is important to consumers and many are willing to pay more for better quality wheat flour. However, farmers do not specifically target quality parameter as their wheat is mostly sold without segregation and premium price (Coventry et al., 2011b).

In South-West Haryana, C-306 and WH-283 varieties are grown to a limited extent with excellent chapatti quality.But these are lower yielding compared with the more widely grown varieties such as PBW-343 and PBW-502 (Coventry et al., 2011b), and it is likely at the present time that farmers will have to manage with these best-quality varieties if they are to obtain premium chapatti quality flour. What is not known is whether the economic returns associated with a practice that does not specifically target optimising grain yield, such as using varieties C-306 and WH-283, will be acceptable to farmers.

In the study reported here, we provide an economic analysis utilising data from extensive field experiments to establish whether an alternative production system that targets chapatti quality is feasible for wheat growers in Haryana. Further, we explore the current processes of wheat and wheat flour purchase based on information from a consumer survey in urban areas of Karnal district (Haryana).

## MATERIALS AND METHODS

### Field sites

During the winter seasons of 2009-2010 and 2010-2011 a series of experiments were conducted in farmer fields to compare wheat productivity and quality between recommended best practice (Coventry et al., 2011a, b, c) and the dominant local farmers' practice. The studies were conducted in split-plot design field experiments with different wheat-based rotations chosen according to location in Haryana. With rice-wheat rotations there were two experiments during the first year.

The first experiment consisting of two varieties (DBW-17 and PBW-550) in the main plot and four management options in sub-plots (local area farmer practice consisted (FP), FP+ micronutrients (MN), recommended practice (SP), SP+ MN). The FP and SP treatments had application of NP (150:26 kg $ha^{-1}$) and NPK (150:26:33 kg $ha^{-1}$) respectively. The fertilizer recommendation for wheat in Haryana is to apply 150 kg N $ha^{-1}$ (2-split schedule: 1/3 at sowing and 2/3 at the first irrigation) and 26 kg P $ha^{-1}$ at sowing (Mishra et al., 2005; Srivastava et al., 2006). In the FP treatment P and some N was applied as basal using di-ammonium phosphate (DAP) and the remaining nitrogen was supplied in two equal splits using urea at the first and second irrigation.

In the SP treatment, P, K and one-third nitrogen were applied as basal and remaining nitrogen in two equal splits through urea at the first and second irrigation. The micronutrients applied were Zn, Fe, Mn, B and Cu and their sources were $ZnSO_4$, $FeSO_4$, $MnSO_4$, Borax and $CuSO_4$, respectively. The concentrations of $ZnSO_4$ (1%), $FeSO_4$ (1%), $MnSO_4$ (0.5%), Borax (0.2%) and $CuSO_4$ (0.2%) were applied as spray solutions. The spraying was done at 55 and 75 days after sowing using a backpack sprayer with a spray volume of 375 L $ha^{-1}$.

In the FP treatment, three to five ploughings along with a harrowing were undertaken prior to sowing. With the SP treatment the seed was direct seeded. The plot size was 4×15 m and sowing was done using a ferti-seed drill with a seed rate of 100 kg $ha^{-1}$. The experiment was conducted at 6 locations (Table 1) located in Karnal, Kaithal and Yamunanagar districts of Haryana. In the second experiment conducted during 2009-2010 in the rice-wheat region, seven varieties (C-306, DBW-17, PBW-343, PBW-502, PBW-550, Raj-3765 and WH-283) with two management strategies (FP and SP+MN) were evaluated at the Darar and Ramba, sites. During 2010-2011 four wheat varieties (C-306, HD-2851, WH-1025 and WH-283) and the above described four management options (FP, FP+MN, SP, SP+MN) were tested at the sites situated in village Ramba, Darar and Kalri.

In the non rice-wheat rotations as practiced in West and South-West Haryana (cotton–wheat, pearl millet–wheat and cluster bean–wheat), an experiment was conducted at six sites (Table 1) during 2009-2010 with the seven varieties (C-306, DBW-17, PBW-343, PBW-502, PBW-550, WH-283 and WH-711) and four nutrient management (FP, FP+MN, SP, SP+MN) treatments. Treatments and management were the same as described above except that $ZnSO_4$ was applied as 25 kg $ha^{-1}$ to all treatments. In the second year (2010-2011), the experiment was conducted at 7 locations (un-replicated) with 4 varieties (C-306, HD-2851, WH-1025 and WH-283) and two management options (FP and SP+MN).

The crops were manually harvested from an area of 2×5 m for grain yield and threshed using a small plot thresher. A random grain sample was taken from each treatment for quality analysis (protein, hardness and chapatti score). Protein was estimated using a standard NIR (Near Infra Red) instrument. The Grain Hardness Index (no units) was determined on about 300 kernels using a Perten model SKCS4100 single kernel characterization system. For the evaluation of chapatti quality, various parameters like water absorption, nature and colour of dough (before and after maturation), chapatti appearance, colour, aroma, taste, puffing height, pliability and loss of water were evaluated by giving a score out of 10. All quality analyses were undertaken at the Wheat Quality Laboratory, Directorate of Wheat Research, Karnal. Soil samples (0 to 10 cm depth) were taken at each of the sites in 2009-2010. Soil analyses were undertaken using standard techniques at the soil testing laboratory, State Department of Agriculture, Karnal (Haryana). For available phosphorus in soil the sodium bicarbonate procedure of Olsen et al. (1954) was used. For available potassium in soil the ammonium acetate solution extraction procedure of Richards (1954) was used and for available sulphur the calcium chloride solution extraction procedure of William and Steinbergs (1959) was used. Zinc, iron and manganese were determined using the DTPA test of Lindsay and Norvell (1978). The agronomy and quality data were subjected to analysis of variance using the GENSAT package.

### Farmer and consumer survey

A farmer survey involving 823 farmers from 103 villages (7 to 8 farmers per block) in 19 of the 21 districts of Haryana, and from each village there were two marginal (<1 ha), two small (1 to 2 ha), two medium (2 to 4 ha) and two large (>4 ha) farmers surveyed. The survey targeted information on current wheat production practices, including information on operational costs, and also information on farmer demographics and attitudes (including understanding of wheat quality and marketing issues). Another survey targeting 200 consumers (personal interview) was conducted in the urban areas of Karnal district covering Radha Swami Market, Saini Colony, Model Town, Dayan and Colony, Sector 4, Sector 6, Sector 8 Part II, Sector 9, DWR-Karnal, NDRI-Karnal and Sadar Bazaar. The wheat market survey was conducted to explore consumers' sources of grain/flour , their preference for

**Table 1.** Soil chemical characteristics for the experimental sites (0-15 cm depth) and sufficiency rating for each measure.

| Site[1] | Rating | pH (1:2) | EC (1:2) dS/m | OC (%) | P (mg kg$^{-1}$) | K (mg kg$^{-1}$) | S (mg kg$^{-1}$) | Zn (mg kg$^{-1}$) | Fe (mg kg$^{-1}$) | Mn (mg kg$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Low | <6.5 | <0.8 | <0.40 | <5.0 | <60 | <10 | <1.0 | <4.5 | <1.0 |
| | Medium | 6.5-8.7 | 0.8-2.5 | 0.40-0.75 | 5-12.5 | 60-140 | 10-20 | 1.0-3.0 | 4.5-9.0 | 1.0-2.0 |
| | High | >8.7 | >2.5 | | >12.5 | >140 | >20 | >3.0 | >9.0 | >2.0 |
| **Rice-Wheat Haryana** | | | | | | | | | | |
| Darar (Karnal) | | 8.3 | 0.36 | 0.39 | 9.23 | 145.0 | 36.2 | 5.3 | 14.1 | 14.9 |
| Ramba(Karnal) | | 8.0 | 0.48 | 0.58 | 8.76 | 156.0 | 28.9 | 7.1 | 12.7 | 14.3 |
| Kalri(Karnal) | | 8.4 | 0.57 | 0.43 | 7.86 | 143.0 | 22.3 | 6.7 | 32.1 | 12.7 |
| Sadura (Yamunanagar) | | 8.5 | 0.47 | 0.35 | 8.16 | 136.7 | 32.9 | 4.5 | 35.7 | 10.9 |
| Thana (Kaithal) | | 8.1 | 0.37 | 0.41 | 9.12 | 155.1 | 25.8 | 7.1 | 29.3 | 8.9 |
| Chhapper (Yamunanagar) | | 8.2 | 0.78 | 0.29 | 7.19 | 148.7 | 21.7 | 5.7 | 15.9 | 9.9 |
| **South West Haryana** | | | | | | | | | | |
| Kapriwas (Riwari)-1 | | 8.0 | 0.30 | 0.16 | 2.11 | 118.3 | 63.0 | 0.59 | 2.65 | 1.08 |
| Tigra (Mahendergarh) 2 & 3 | | 8.3 | 0.44 | 0.16 | 1.39 | 62.3 | 35.8 | 0.50 | 0.76 | 1.08 |
| Tigra (Mahendergarh) - 4 | | 8.3 | 0.38 | 0.24 | 1.27 | 105.8 | 34.0 | 1.39 | 0.29 | 0.75 |
| Begu Sahapur (Sirsa) - 5 | | 8.2 | 0.44 | 0.25 | 2.35 | 282.2 | 67.7 | 1.74 | 2.21 | 2.41 |
| Bhangu (Sirsa) - 6 | | 8.6 | 0.71 | 0.22 | 1.90 | 170.2 | 96.7 | 1.14 | 3.82 | 1.97 |

[1] Village and district (parentheses).

days after sowing using a backpack sprayer with a spray volume different brands, present and future consumption pattern of wheat based products and their sensitivity to price and quality.

### Marginal analysis

Data from the field experiments were used for providing comparative data in a marginal analysis that compares the benefits and costs of the different management alternatives used (FP, FP+MN, SP and SP+MN). By examining the incremental change on total revenue and total cost for any change in the output and input used in each alternative, the best economic practice was determined. Operational costs were the only costs considered in establishing the profitability of the selected farming practice. The operational costs include expenses on labour employed to perform different cultural operations and expenses incurred on material inputs *viz.,* seeds, manure, fertilisers, plant protection chemicals, irrigation, micro-nutrients and herbicide (Table 7). These costs were collected from the farm survey conducted in Haryana during 2010. Gross returns (price x yield) and net returns (gross returns minus operational costs) were calculated to establish the margin accrued to the farmer after meeting all working expenses. Benefit-Cost ratio (Gross Income ÷ Operational costs) and net returns per rupee of investment (Net returns ÷ Operational costs) were thus calculated for each farming practice (Table 8).

## RESULTS

### Site characteristics

The sites chosen for the farm-based experiments were typical of both the rice-wheat (RW) regions of Haryana, and the non rice wheat areas in south-west Haryana (SW) where cotton, pearl millet and cluster bean (but not rice) are included in the rotation (Table 1). The soils of all the sites were alkaline (pH 8.0 to 8.6) in nature with low-medium electrical conductivity (0.29 to 0.78 dSm$^{-1}$) and low organic matter. The values for phosphorus from all the sites were very low whilst sulphur and potassium were in the high range. Zinc was high in the RW rotation (> 4.5 mg kg$^{-1}$) but was in the low-medium range for the SW sites (0.5 to 1.7 mg kg$^{-1}$). Iron and manganese had a similar pattern with the higher measures in the RW sites and low-medium measures in the SW sites.

**Table 2.** Mean values for grain yield, protein, hardness and chapatti score for 6 sites and 4 management treatments in rice-wheat rotations, 2009-2010 season.

| Site | Grain yield ($tha^{-1}$) | | | | Protein (%) | | | | Hardness (%) | | | | Chapatti score (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FP[1] | FP+MN | SP | SP+MN | FP | FP+MN | SP | SP+MN | FP | FP+MN | SP | SP+MN | FP | FP+MN | SP | SP+MN |
| Ramba | 5.5 | 6.3 | 6.2 | 5.8 | 11.72 | 12.02 | 12.19 | 12.55 | 73.8 | 76.8 | 79.8 | 82.2 | 7.46 | 7.54 | 7.61 | 7.69 |
| Darar | 4.6 | 5.4 | 4.9 | 5.4 | 11.82 | 11.95 | 12.18 | 12.45 | 75.0 | 77.5 | 80.7 | 82.8 | 7.43 | 7.54 | 7.64 | 7.69 |
| Kalari | 4.1 | 4.7 | 4.2 | 4.6 | 11.58 | 11.87 | 12.05 | 12.41 | 71.0 | 74.7 | 77.5 | 79.2 | 7.42 | 7.47 | 7.55 | 7.64 |
| Thana | 3.4 | 3.7 | 2.9 | 3.2 | 11.94 | 12.06 | 12.46 | 12.77 | 77.7 | 80.8 | 83.8 | 86.5 | 7.53 | 7.59 | 7.68 | 7.75 |
| Sadura | 5.4 | 5.7 | 4.9 | 5.1 | 11.23 | 11.51 | 11.69 | 12.05 | 68.8 | 72.0 | 75.8 | 77.3 | 7.38 | 7.44 | 7.52 | 7.60 |
| Chapper | 3.9 | 4.3 | 4.5 | 5.0 | 10.83 | 11.14 | 11.30 | 11.64 | 69.5 | 72.0 | 74.7 | 77.2 | 7.28 | 7.37 | 7.46 | 7.53 |
| Site | 0.3 | | | | 0.2 | | | | 1.9 | | | | 0.07 | | | |
| Management | 0.3 | | | | 0.2 | | | | 1.6 | | | | 0.06 | | | |
| sitexmgt | 0.6 | | | | ns | | | | ns | | | | | | | |

[1]FP - Local area farmer practice; FP+MN – FP + micronutrients; SP - recommended practice; SP+ MN – SP + micronutrients.

## Grain yield and quality data

In the rice-wheat region in the experiment located at six sites (2009-2010) there were positive responses with grain yield to the additional management compared with the recommended farmer practice, although these responses differed in extent between sites (site x management interaction) (Table 2). Four of the six sites had higher grain yield where the SP treatment was used, and at all sites the addition of the micronutrient supplements gave extra yield (mean 8.2%), except one location (Ramba). Three quality measures reported here show a consistent step-wise response pattern at all sites, with both the SP treatment and the addition of micronutrients resulting in extra protein, grain hardness and chapatti score (Table 2). Regarding the quality measures there were no interactions between management and the grains sourced from the different sites. In this experiment, DBW-17 and PBW-550 (mean data shown) varieties were chosen because they represent different protein extremes, with DBW-17 being a high protein variety (Table 3). In the second experiment, wheat varieties, DBW-17, PBW-343, PBW-502, PBW-550 produced similar grain yield, whereas C-306 had less grain yield by about 40% and WH-283 less by 23% compared to PBW-502. In this experiment there was no significant response to the additional management input with grain yield, but this enhanced management package resulted in higher protein, grain hardness and chapatti score with all varieties. C-306 and WH-283 had the highest measures for chapatti quality (grain hardness and chapatti score) while PBW-502, PBW-550 and Raj-3765 showed poorest chapatti quality measures. The variety PBW-550 had the lowest protein and Raj-3765 the highest protein. In the 2010-2011 growing season two other varieties were compared with the two recognised high quality varieties (C-306, WH-283). HD-2851 which is a variety well adapted to late sowing had much higher yield (>46%) than C-306, but the grain yield of WH-1025 was only similar to C-306 in this environment (Table 4). Similarly to the variety experiment in the previous season the quality measures increased in a stepwise manner with the management inputs (Table 4). HD-2851 is also known as a high protein cultivar, but was not comparable to C-306 and WH-283 with respect to chapatti quality parameters.

With the sites used in the west (cotton-wheat) and south-west (pearl millet/cluster bean-wheat) areas of Haryana there were some small increases in grain yield with the improved practice (SP) compared with the farmer practice (FP) and with micronutrients alone. However, where both SP and micronutrients were used together there was a consistent yield increase of about 4 to 5% at all sites (Table 5). Of the two improved management components, micronutrients had the biggest effect on protein, but SP also increased protein and there were similar increases with hardness and chapatti score responses. There was a site x management interaction for these quality measurements, with the cotton-wheat sites being more responsive to the improved management inputs (Table 5). In the same experiment where varieties were compared at these six sites, PBW-343, DBW-17, PBW-502, PBW-550, and WH-711 all had much the same

**Table 3.** Mean values for grain yield, protein, hardness and chapatti score for 2 sites, 7 varieties and 4 management treatments in rice-wheat rotations, 2009-2010 season.

| Site | Grain yield ($tha^{-1}$) | | | | Protein (%) | | | | Hardness (%) | | | | Chapatti score (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ramba | | Darar | | Ramba | | Darar | | Ramba | | Darar | | Ramba | | Darar | |
| | FP | SP+MN | FP | SP+MN | FP | SP+MN | FP | SP+MN | FP | SP+MN | FP | SP+MN | FP | SP+MN | FP | SP+MN |
| C-306 | 4.17 | 4.75 | 3.72 | 4.18 | 11.89 | 11.99 | 12.07 | 12.13 | 92.5 | 95.5 | 96.25 | 98 | 8.08 | 8.17 | 8.15 | 8.22 |
| DBW-17 | 6.54 | 5.56 | 6.08 | 5.81 | 12.00 | 12.19 | 12.20 | 12.35 | 81.25 | 85.5 | 84.5 | 89.75 | 7.63 | 7.74 | 7.75 | 7.77 |
| PBW-343 | 6.22 | 5.19 | 6.03 | 5.38 | 11.98 | 11.99 | 11.93 | 12.16 | 79.25 | 82 | 82 | 85.75 | 7.51 | 7.64 | 7.62 | 7.68 |
| PBW-502 | 5.74 | 5.84 | 6.57 | 5.52 | 11.82 | 11.84 | 12.03 | 11.99 | 73.25 | 75.75 | 76.25 | 80 | 7.43 | 7.52 | 7.52 | 7.59 |
| PBW-550 | 6.15 | 5.59 | 5.96 | 5.63 | 11.23 | 11.44 | 11.44 | 11.87 | 76.75 | 79.25 | 79.5 | 82.5 | 7.36 | 7.45 | 7.48 | 7.53 |
| Raj-3765 | 4.68 | 5.00 | 5.33 | 5.03 | 12.15 | 12.43 | 12.37 | 12.60 | 72.75 | 76 | 75.75 | 79.5 | 7.62 | 7.74 | 7.70 | 7.79 |
| WH-283 | 4.85 | 5.02 | 4.63 | 5.02 | 11.59 | 11.75 | 11.78 | 11.91 | 93.75 | 96.5 | 96.75 | 100.25 | 8.03 | 8.09 | 8.14 | 8.12 |
| Site | 0.21 | | | | 0.13 | | | | 1.2 | | | | 0.03 | | | |
| Mgt | ns | | | | 0.13 | | | | 1.2 | | | | 0.03 | | | |
| Variety | 0.39 | | | | 0.24 | | | | 2.26 | | | | 0.05 | | | |
| Sitexvar | 0.55 | | | | | | | | | | | | | | | |

**Table 4.** Mean values for grain yield, protein, hardness and chapatti score for 4 varieties and 4 management treatments in rice-wheat rotations, mean of three sites, 2009-2010 season.

| Site | Grain yield ($tha^{-1}$) | | | | Protein (%) | | | | Hardness (%) | | | | Chapatti score (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FP | FP+MN | SP | SP+MN | FP | FP+MN | SP | SP+MN | FP | FP+MN | SP | SP+MN | FP | FP+MN | SP | SP+MN |
| C-306 | 2.99 | 2.93 | 3.04 | 3.06 | 10.75 | 11.16 | 11.65 | 12.09 | 96.67 | 99.89 | 102.44 | 106.00 | 7.97 | 8.08 | 8.19 | 8.28 |
| HD-2851 | 4.38 | 4.20 | 4.45 | 4.68 | 11.24 | 11.71 | 12.14 | 12.74 | 88.56 | 92.33 | 93.89 | 97.11 | 7.84 | 7.92 | 7.99 | 8.06 |
| WH-1025 | 2.99 | 2.89 | 2.96 | 2.99 | 11.29 | 11.52 | 11.99 | 12.34 | 86.56 | 91.33 | 96.00 | 99.22 | 7.79 | 7.90 | 7.97 | 8.05 |
| WH-283 | 3.98 | 3.87 | 4.12 | 4.33 | 11.34 | 11.83 | 12.37 | 12.69 | 92.89 | 96.22 | 98.99 | 101.67 | 7.92 | 7.98 | 8.07 | 8.15 |
| variety | 0.15 | | | | 0.19 | | | | 1.42 | | | | 0.03 | | | |
| Mgt | 0.15 | | | | 0.19 | | | | 1.42 | | | | 0.03 | | | |
| Varxmgt | | | | | | | | | | | | | | | | |

yield, and WH-283 had 4% less grain yield and C-306 had 28% less yield compared to PBW-502. There was a significant variety x site interaction. Higher yielding varieties performed much better than C-306 at the higher yielding sites (eg. Site 5). Varieties C-306 and WH-283 had the highest quality measures (Table 6 – only grain hardness shown), with WH-711 next highest, and PBW-502 and PBW-550, the lowest. In 2010-2011, the full management package did not influence grain yield but protein and hardness, in-line with other seasons and locations were increased by 10 to 15% (data not shown). At these western locations, HD-2851 yielded 32% higher than C-306 and WH-1025 the same as C-306.

## Marginal analysis

Data from the farm survey undertaken in 2010 was used to establish the operational costs

**Table 5.** Mean values for grain yield, protein, hardness and chapatti score for 6 sites and 4 management treatments in SW Haryana rotations, 2009-2010 season.

| Site | Grain yield (tha$^{-1}$) | | | | Protein (%) | | | | Hardness (%) | | | | Chapatti score (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FP | FP+mn | SP | SP+mn | FP | FP+mn | SP | SP+mn | FP | FP+mn | SP | SP+mn | FP | FP+mn | SP | SP+mn |
| Kapriwas(PM-W) | 4.21 | 4.38 | 4.25 | 4.40 | 10.73 | 11.29 | 11.10 | 11.59 | 77.75 | 81.89 | 80.07 | 84.96 | 7.55 | 7.61 | 7.57 | 7.65 |
| Tigra 1(PM-W) | 4.95 | 5.02 | 5.04 | 5.21 | 10.52 | 11.05 | 10.85 | 11.38 | 75.75 | 79.57 | 78.61 | 83.50 | 7.50 | 7.55 | 7.54 | 7.59 |
| Tigra 1(CB-W) | 4.39 | 4.44 | 4.43 | 4.54 | 10.97 | 11.48 | 11.29 | 11.78 | 75.50 | 81.32 | 82.57 | 84.43 | 7.46 | 7.66 | 7.53 | 7.71 |
| Tigra 2(CB-W) | 5.15 | 5.26 | 5.22 | 5.36 | 10.66 | 11.49 | 11.31 | 11.83 | 76.07 | 83.96 | 82.36 | 87.25 | 7.49 | 7.68 | 7.65 | 7.71 |
| BeguSahapur(C-W) | 4.82 | 4.90 | 4.90 | 5.07 | 10.72 | 11.66 | 11.31 | 12.02 | 79.07 | 84.93 | 82.46 | 89.61 | 7.56 | 7.78 | 7.74 | 7.83 |
| Bhangu (C-W) | 4.16 | 4.25 | 4.18 | 4.35 | 10.97 | 11.87 | 11.50 | 12.23 | 80.21 | 86.75 | 84.39 | 91.07 | 7.49 | 7.71 | 7.67 | 7.73 |
| Site | 0.08 | | | | 0.03 | | | | 0.48 | | | | 0.01 | | | |
| Mgt | 0.07 | | | | 0.03 | | | | 0.39 | | | | 0.01 | | | |
| sitexmgt | Ns | | | | 0.06 | | | | 0.52 | | | | 0.02 | | | |

**Table 6.** Mean values for grain yield and hardness for 6 sites and 7 varieties in SW Haryana rotations, 2009-10 season.

| Site[1] | Grain yield (t ha$^{-1}$) | | | | | | | Grain hardness (%) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C-306 | DBW-17 | PBW-343 | PBW-502 | PBW-550 | WH-283 | WH-711 | C-306 | DBW-17 | PBW-343 | PBW-502 | PBW-550 | WH-283 | WH-711 |
| Site 1 | 3.52 | 4.64 | 4.58 | 4.68 | 4.19 | 4.28 | 4.98 | 89.8 | 80.8 | 76.3 | 71.6 | 75.3 | 89.3 | 85.3 |
| Site 2 | 3.76 | 5.31 | 5.34 | 5.46 | 5.25 | 5.07 | 5.33 | 87.6 | 79.5 | 74.4 | 69.6 | 73.3 | 87.6 | 83.4 |
| Site 3 | 3.64 | 4.66 | 4.70 | 4.75 | 4.43 | 4.48 | 4.97 | 88.8 | 80.5 | 76.2 | 73.1 | 72.6 | 90.6 | 84.9 |
| Site 4 | 3.82 | 5.47 | 5.62 | 5.62 | 5.50 | 5.30 | 5.49 | 91.1 | 81.6 | 77.6 | 73.0 | 76.5 | 90.6 | 86.6 |
| Site 5 | 3.40 | 5.27 | 5.10 | 5.30 | 5.22 | 5.00 | 5.64 | 92.9 | 83.6 | 79.1 | 74.6 | 78.0 | 92.2 | 87.8 |
| Site 6 | 3.35 | 4.47 | 4.33 | 4.47 | 4.44 | 4.26 | 4.69 | 94.8 | 85.4 | 80.8 | 76.3 | 79.5 | 93.6 | 88.9 |
| Site | 0.083 | | | | | | | 0.48 | | | | | | |
| variety | 0.089 | | | | | | | 0.52 | | | | | | |
| site x var | 0.219 | | | | | | | 1.27 | | | | | | |

[1]For site location (Table 5).

(shown in Indian Rupee (INR); 1USD = 48 INR) for the four management practices (FP, FP+MN, SP, SP+ MN) used in the experiments reported here that were undertaken on farmer fields in the rice-wheat areas (RW) and the western and south-western areas (SW) (Table 7). Marginal analysis was done comparing three wheat varieties, PBW-502 representing the currently recommended high yield variety, and, C-306 and WH-283 two varieties that are recognised as 'best quality' for chapattis (Table 8). Based on the data from these experiments, a 2% yield gain was assumed for the SP treatment compared with FP, and a 3% yield gain was assumed where MN was included. A yield of 5.5 tha$^{-1}$ was allocated to PBW-502 for RW and 5.0 tha$^{-1}$ for SW and C-306 was assumed to yield 40 and 30% less than PBW-502 in the RW and SW areas respectively, and WH-283 to yield 25 and 5% less than PBW-502 in these regions. The market prices available at the time for these 3 varieties were INR 11000 and11700 (PBW-502) (Ministry of Agriculture, Government of India, 2012), and around INR 20000 (C-306) and INR 15000 (WH-283) per

**Table 7.** Operational costs (INR) associated with wheat production, Haryana, India.

| **Particulars** | **Haryana** | | | |
|---|---|---|---|---|
| | **FP** | **FP+MN** | **SP** | **SP+MN** |
| Field preparation | 3256.50 | 3256.50 | -- | -- |
| Seed | 1803.87 | 1803.87 | 1803.87 | 1803.87 |
| Sowing | 1238.34 | 1238.34 | 1238.34 | 1238.34 |
| Irrigation charges | 2350.31 | 2350.31 | 2350.31 | 2350.31 |
| Herbicide and application | 1158.03 | 1158.03 | 1158.03 | 1158.03 |
| Fertiliser and application | 1772.00 | 1771.00 | 2237.00 | 2237.00 |
| Plant protection chemicals application | 1116.92 | 1116.92 | 1116.92 | 1116.92 |
| Micro nutrients | - | 2236.30 | - | 2236.30 |
| Micro nutrients application | - | 518.92 | - | 518.92 |
| Harvesting | 3530.78 | 3530.78 | 3530.78 | 3530.78 |
| Threshing | 1725.31 | 1725.31 | 1725.31 | 1725.31 |
| Marketing cost | 500.00 | 500.00 | 500.00 | 500.00 |
| **Total operational costs** | **18452.06** | **21206.28** | **15660.56** | **18415.78** |

tonne (usually 1.5 to 2 times higher than minimum support price fixed by the Government of India on the recommendation of Commission for Agricultural, Costs and Prices).Of all the combinations shown in Table 8, growing WH-283 in the SW region with the SP treatment was the most profitable operation. The second most profitable outcome was growing C-306 in the SW region with the SP treatment. With all the combinations using the SP treatment was on average 9% more profitable, but where the micronutrient mix was included there was a 2.4% loss obtained (Table 8).

## Consumer survey

The average family size of the respondents to the consumer survey was 4.52. About 84% of respondents purchased/retained wheat grain; this was either from the market (58%), directly from farmers (18%) and those who had rural background and retained produce from their own farm (8%). The average amount purchased was 358 kg wheat grain for their annual consumption. The respondents who kept their own produce had 360 kg wheat for annual consumption. The remainder of the respondents (16%) purchased flour either from retailers (14.5%) or mini flour mills (1.5%). They purchased a local brand (*Brand A*) solely (10%), *Brand A* and sometimes a more expensive brand (*Brand B*) (1.5%) and solely *Brand B* (3%) flour. Most of the respondents (70%) who purchased *Brand A* flour made comments about quality concerns. All respondents were satisfied with the quality of *Brand B* flour, and although they look for better quality flour usually the preference is to seek lower price. The respondents purchased flour mainly for making chapatti, although 3.5% of those who purchased flour from the retailers used it for indigenous products like *halwa (a* sweet dish served to the guests or prepared on the occasion of festivals for their own consumption), *puri* (small sized chapatti deep fried in ghee/ vegetable oils) and noodles. The respondents reported that the consumption pattern is changing and the younger generation is increasingly more inclined towards pasta, bread and noodle (wheat based products). Within the farmer survey of farmers throughout the 19 districts surveyed (total 823 farmers; data used in Table 7), 19.8% reported some direct marketing to the consumers of their wheat harvest.

## DISCUSSION

Given the intensity of crop production in Haryana (182% annual cropping intensity), particular concern is taken in monitoring the on-going nutrient status of these soils (Singh, 2008). In the field experiments reported here, and in previous experiments (Coventry et al., 2011a), where a mix of micronutrients plus sulphur was applied, there were small (3%) increases in grain yield obtained, and consistent and larger increases in grain protein, hardness and chapatti quality. However the application of this 'shot-gun' mix of nutrients was not economic within this wheat phase of the rotation (Table 8). A recent survey has identified more than 50% of Haryana soils as deficient in Zn (Quinquennial Report, 2005-2006), and this trend isevident in the SW sites used here, but it is not evident in the main rice-wheat districts where the Zn levels have been improved by regular supplementation in the rice phase of the rotation. Nearly all sites used here would be classified as having adequate or high S, although within non-rice districts where S is rarely applied there are some reports of areas of S deficiency (Hegde and Babu, 2007). The lack of S can limit the efficiency of N utilisation in

**Table 8.** Marginal economic analysis for 3 wheat varieties with different production practices in Haryana, India.

| Variety | Particulars | Unit | RW | | | | SW | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | FP | $FP_{MN}$ | SP | $SP_{MN}$ | FP | $FP_{MN}$ | SP | $SP_{MN}$ |
| PBW-502 | Yield | $tha^{-1}$ | 5.50 | 5.67 | 5.61 | 5.78 | 5.00 | 5.15 | 5.10 | 5.25 |
| | Change in yield | % | - | 3 | 2 | 3 | - | 3 | 2 | 3 |
| | Price of output | INR $t^{-1}$ | 11000 | 11000 | 11000 | 11000 | 11000 | 11000 | 11000 | 11000 |
| | Value of output | INR $ha^{-1}$ | 60500 | 62315 | 61710 | 63561 | 55000 | 56650 | 56100 | 57783 |
| | Operational costs | INR $ha^{-1}$ | 18452 | 21206 | 15661 | 18416 | 18452 | 21206 | 15661 | 18416 |
| | Net income | INR $ha^{-1}$ | 42048 | 41109 | 46049 | 45146 | 36548 | 35444 | 40439 | 39367 |
| | Benefit-Cost ratio (Operational costs) | INR $ha^{-1}$ | 3.28 | 2.94 | 3.94 | 3.45 | 2.98 | 2.67 | 3.58 | 3.14 |
| | Net returns per rupee of investment | INR $ha^{-1}$ | 2.28 | 1.94 | 2.94 | 2.45 | 1.98 | 1.67 | 2.58 | 2.14 |
| | Change in profit over respective categories | % | | -2.24 | 9.52 | -1.96 | | -3.02 | 10.65 | -2.65 |
| C-306 | Yield | $tha^{-1}$ | 3.30 | 3.40 | 3.37 | 3.47 | 3.50 | 3.61 | 3.57 | 3.68 |
| | Change in yield | % | -40 | 3 | 2 | 3 | -30 | 3 | 2 | 3 |
| | Price of output | INR $t^{-1}$ | 20000 | 20000 | 20000 | 20000 | 20000 | 20000 | 20000 | 20000 |
| | Value of output | INR $ha^{-1}$ | 66000 | 67980 | 67320 | 69340 | 70000 | 72100 | 71400 | 73542 |
| | Operational costs | INR $ha^{-1}$ | 18452 | 21206 | 15661 | 18416 | 18452 | 21206 | 15661 | 18416 |
| | Net income | INR $ha^{-1}$ | 47548 | 46774 | 51659 | 50924 | 51548 | 50894 | 55739 | 55126 |
| | Benefit-Cost ratio (Operational costs) | INR $ha^{-1}$ | 3.58 | 3.21 | 4.30 | 3.77 | 3.79 | 3.40 | 4.56 | 3.99 |
| | Net returns per rupee of investment | INR $ha^{-1}$ | 2.58 | 2.21 | 3.30 | 2.77 | 2.79 | 2.40 | 3.56 | 2.99 |
| | Change in profit over respective categories | % | | -1.63 | 8.65 | -1.42 | | -1.27 | 8.13 | -1.10 |
| WH-283 | Yield | $tha^{-1}$ | 4.13 | 4.25 | 4.21 | 4.33 | 4.75 | 4.89 | 4.85 | 4.99 |
| | Change in yield | % | -25 | 3 | 2 | 3 | -5 | 3 | 2 | 3 |
| | Price of output | INR $t^{-1}$ | 15000 | 15000 | 15000 | 15000 | 15000 | 15000 | 15000 | 15000 |
| | Value of output | INR $ha^{-1}$ | 61875 | 63731 | 63113 | 65006 | 71250 | 73388 | 72675 | 74855 |
| | Operational costs | INR $ha^{-1}$ | 18452 | 21206 | 15661 | 18416 | 18452 | 21206 | 15661 | 18416 |
| | Net income | INR $ha^{-1}$ | 43423 | 42525 | 47452 | 46590 | 52798 | 52181 | 57014 | 56439 |
| | Benefit-Cost ratio (Operational costs) | INR $ha^{-1}$ | 3.35 | 3.01 | 4.03 | 3.53 | 3.86 | 3.46 | 4.64 | 4.06 |
| | Net returns per rupee of investment | INR $ha^{-1}$ | 2.35 | 2.01 | 3.03 | 2.53 | 2.86 | 2.46 | 3.64 | 3.06 |
| | Change in profit over respective categories | % | | -2.07 | 9.28 | -1.82 | | -1.17 | 7.99 | -1.01 |

field crops and although with the high yields obtained with the wheat used here there will be a high demand for N, it is still unlikely that there would be any NxS interactions evident given 150 kg $Nha^{-1}$ was applied (Jamal et al., 2010). Despite the sites receiving regular inputs of P fertiliser at recommended rates (26 kg P $ha^{-1}$) the soil measures for P are in the low range, prompting Coventry et al. (2011a) to suggest that this recommended rate may be too low for soil P maintenance levels. Manganese and iron levels were mostly in the high range from the rice-wheat sites, but the levels at all the non-rice sites are low (Table 1; Singh, 2008).This difference may be due to the continuous submergence and wet tillage during the rice cycle, rather than to any inherent soil differences. The reduced conditions created by wet tillage (puddling) and ponding of water has many benefits such as neutralizing soil pH to improve the availability of plant nutrients (P, K, Ca, Mg, Mn, Fe) and also allow for accumulation of organic matter (Ponnamperuma, 1972; Sahrawat, 2005). Copper is another micronutrient that has been identified as deficient over much of Haryana but was not measured here. Haryana State has already targeted subsidy schemes available for micronutrients and gypsum, and given the intensive nature of the production systems, the use of selected micronutrients and sulphur is an essential requirement. Thus monitoring and targeting specific crop requirements is required as part of best practice management.

Various authors have shown that there is no grain yield penalty, and there may be some yield advantage, where zero till seeding practice is used rather than using multiple cultivations prior to seeding (Coventry et al., 2011a; Erenstein and Laxmi, 2008; Erenstein et al., 2008; Kumar et al., 2006; Malik et al., 2002; Singh et al., 2006; Yadav and Malik, 2005). Indeed already 25% of the wheat crop in Haryana is sown using a zero till practice. Coventry et al. (2011c) have also shown that a 3-way split with the recommended N application rate (150 kg N $ha^{-1}$) can increase grain yield in the SW region. Thus, we have used both zero till and the 3-way split of N-fertiliser underpinning the best practice (SP) treatment in the 2 years of field trials. Consistent with our previous work we only obtained small (or none) grain yield increases, but always had substantial improvements in all chapatti quality measures irrespective of the wheat variety used. Whilst here we could not discriminate between the component differences in the SP treatment, for the marginal analysis we assumed a 2% yield improvement with this recommended practice, and given the large cost saving associated with not undertaking the 4 cultivations, this SP treatment was always the most profitable (by 9%). Even if we had allowed for no yield improvement, the SP treatment would be 6.7% more profitable.

The most profitable outcome from the examples used here involves taking advantage of the higher price available for grain from either the recognised standard for best quality chapatti flour (C-306) or variety WH-283. In the SW region, the net return per rupee of investment was 3.64 where WH-283 was grown compared with a net return of 2.58 where the high yielding PBW-502 was grown. In the SW region, WH-283 only has a small yield disadvantage (5%) compared with the best yielding standards. In the rice-wheat area the best financial outcome was obtained using variety C-306 (net return 3.30) compared with a return of 2.28 when PBW-502 was used. It should be repeated here that C-306 is an old variety (released in 1966) that produces 30 to 40% less grain than the current recommended wheat varieties, but this disparity can be much higher as this tall variety is susceptible to lodging, and does not have the armoury of genetic protection assembled with cumulative advances in breeding. There is concern that traditional agriculture with wheat as the main winter crop is not a profitable venture due to squeezed margins given the low and mostly static support price given by the government. At present, wheat cultivation earns farmers an annual profit of about INR 20,000 to 24,000 per ha (Kharkar, 2012; CACP Report, 2012), so farmers are looking for options to diversify systems to increase profitability.

The past three seasons have seen record high yields of wheat in Haryana and this outcome is an on-going priority for India, both for raising external income and for ensuring basic food availability for the large population. Thus, the variety improvement programs target high yield and particularly management of yellow rust (*Puccinia striiformis*). Therefore, any wholesale change in wheat production that moves farmers away from optimizing total grain production is untenable. Notwithstanding this reality, some farmers are in a better position to take advantage of the marketing situation as it currently exists. The yield data shows that the current two 'best-quality' varieties (C-306 and WH-286) suffer large yield penalties when grown in the rice-wheat districts, but in the west and south-west areas of Haryana, C-306 yield is relatively not as much affected compared with the RW situation (25% compared with 40%) and WH-283 grain yield is only minimally affected. Therefore at this stage it is likely that little opportunity exists for farmers to be seeking the quality markets in the rice-wheat areas, and that more realistic market opportunities exist in the SW areas where the practice is already better suited for quality. Two additional varieties (HD-2851 and WH-1025) that have good chapatti quality were evaluated here, and HD-2851 performed well with quality and also yield. Whilst quality is routinely evaluated as part of the various wheat improvement programs, there must be awareness for quality within localised markets and special market opportunities. Wheat currently is purchased largely by government agencies based on a minimum support price (MSP), irrespective of any quality traits. From the surveys undertaken and reported here we know that the local marketing of grain is an active market and about 18% of farmers sell their grain outside the MSP. In the SW region, a few villages are already actively undertaking locally based marketing of chapatti quality wheat, and varieties WH-283 and C-306 are being grown by many farmers covering an area of about 10% in Rewari and Mahendergarh districts (Coventry et al., 2011b). Generally in the rice-wheat system, the farmers are more concerned about high wheat yield and few farmers (2%) expressed an interest in growing quality wheat, mainly because they feared that they may not get market recognition for the quality produce.

We have shown that it is possible to improve the chapatti quality of wheat within all the varieties evaluated using best practice management (zero tillage and split applications of N-fertiliser). However, it is unlikely that this quality outcome is likely to be a motivator for farmers without some financial recognition. As India seeks more opportunities in the wheat export markets, the move towards segregation of wheat into targeted markets is developing. Segregation at the large scale will become more plausible as better quality attributes are available in the high yielding varieties. As these specific markets develop, more Indian wheat farmers will have incentives for the production of high quality chapatti wheats.

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