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Management strategies for sustainable wheat production in Pakistan – a review

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Abstract

Sustainable wheat production in Pakistan relies on integrated best management practices that encompass land preparation, sowing methods, planting timing, weed control, balanced fertilization, irrigation scheduling, and disease management. Optimized land preparation techniques, including tillage sequencing, laser land leveling, and precise field surveying, enhance seedbed conditions, improve water use efficiency, and significantly increase yields. Modern sowing techniques such as ridge, raised-bed, and drill planting outperform traditional broadcasting methods, resulting in yield increases of 9–22% and water savings. Timely planting, especially early sowing with suitable varieties, is vital for avoiding thermal stress and maximizing grain development. Effective weed control using appropriate herbicides can prevent annual yield losses of 17–25%, while balanced fertilization guided by soil testing can boost production by up to 70%. Efficient irrigation scheduling based on crop water requirements and groundwater contributions helps prevent nutrient loss, waterlogging, and soil health decline. Additionally, proactive disease management particularly against rusts, root rot, smut, and black point through resistant varieties, timely fungicide applications, and optimized sowing times is essential for protecting yields. Collectively, these practices form a comprehensive framework for enhancing wheat productivity, water efficiency, and sustainability across Sindh and other wheat-growing regions of Pakistan. This review provides an extensive overview of best management practices that can guide farmers, researchers, and policymakers toward more efficient and sustainable wheat cultivation.

Keywords: Irrigation scheduling, Land preparation, Planting time, Sowing methods, Wheat cultivation.

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Contents

Contribution of this paper to the literature
This article reviews the causes of low wheat yield and potential yield gaps in Pakistan. The article argues that higher wheat yields are only possible through an integrated approach involving proper land preparation, timely sowing of crops, balanced use of fertilizers, weed and disease management, and irrigation scheduling.

1. Introduction

Pakistan's food security and rural economy are heavily dependent on wheat (*Triticum aestivum* L.), which serves as the staple diet for over 200 million people. Beyond its importance for human consumption, wheat straw remains a valuable by-product used for livestock feed, paper manufacturing, and other agro-based industries, reaffirming its central role in both agricultural and industrial sectors. Despite this significance, Pakistan's wheat productivity continues to fall short of its potential. In 2023–24, wheat was cultivated on an area of 9.7348 million hectares, producing 31.8145 million tonnes, with an average yield of 3,268.1 kg/ha [1]. Although this reflects modest progress, it remains well below the potential yield of improved varieties, estimated between 5,000 and 8,000 kg/ha. This persistent yield gap highlights the urgency for targeted interventions in policy and practice. Major constraints include inefficient on-farm crop irrigation practices, imbalanced fertilizer application, delayed sowing, inadequate crop rotation, and limited adoption of climate-smart technologies. Post-harvest losses, poor seed quality, and insufficient farmer training further exacerbate the problem. Bridging these gaps requires an integrated approach that combines technological innovation with institutional support. Practices such as proper land preparation for sowing (including laser land leveling), sowing techniques, irrigation scheduling, and balanced nutrient management can enhance input efficiency and yield stability. Strengthening extension services, ensuring access to certified seeds, and promoting mechanization will empower farmers to adopt improved practices. Equally important is aligning agricultural policies with research-based recommendations, including incentives for water-efficient irrigation and soil health restoration. Enhancing wheat productivity is not merely an agronomic objective; it is a national imperative for ensuring food security, economic resilience, and sustainable rural livelihoods under increasing climate and resource pressures. This review article provides a comprehensive overview of best management practices that can guide farmers, researchers, and policymakers toward more efficient and sustainable wheat cultivation.

2. Strategies for Sustainable Wheat Production

2.1. Land Preparation

Proper land preparation is highly important for achieving the productive potential of wheat. It is a fundamental requirement for successful wheat cultivation, influencing every crop growth stage from germination to ripening. These stages include seedling establishment (root development), tillering, stem elongation, booting (head formation inside the leaf sheath), heading (emergence of the head), flowering (anthesis), and finally, grain filling and ripening. Properly prepared soil ensures optimal seed-to-soil contact, moisture conservation, and aeration, all of which are prerequisites for achieving high yields. An optimized tillage operation for land preparation can increase wheat yield by 13 – 30% [2]. Research on the performance of different tillage implements on wheat crops in Toba Tek Singh, Punjab, Pakistan, shows that after harvesting the previous crop and before sowing wheat, a sequence of tillage operations is ideal. This sequence includes one pass of a mould board plough (to invert the soil and incorporate residues of the previous crops), a disc harrow (to ensure fine tilth and proper leveling), a rotavator, and a planking or cultivator (to crush clods and refine the seedbed) [2].

For wheat cultivation through drill sowing and raised bed sowing, after applying the soaking dose when the soil reaches a favorable condition for sowing (tractors can operate without wheel slippage and there is sufficient moisture for seed germination), two passes of a disc harrow and one pass of a cultivator should be performed. Subsequently, a drill machine for drill sowing and a raised bed planter for raised bed sowing should be operated. However, if wheat is to be sown on ridges (after the final harvest of the previous crop), only the mould board, disc harrow, and cultivator should be used (each once), and then ridges should be prepared with a ridge maker.

A precisely leveled land facilitates uniform irrigation application, which leads to reduced water and nutrient losses through runoff and deep percolation. It also provides a basis for more uniform crop establishment. To achieve this, the use of a laser land leveler is very important, typically after every three years of cropping. Research conducted on farmers' fields within Pakistan, specifically in the district of Sargodha, indicates that precisely leveled land needs to be re-leveled after three years. Moreover, the costs incurred for laser land leveling are recovered within one season [3]. If farmers rely on traditional land leveling using tractor-drawn levelers, then major crops under conventional leveling consume 51% more water, with a yield reduction of 6–10%, and exhibit 33–38% lower water use efficiency, along with a 32% decrease in net annual income compared to fields leveled with a laser land leveler [3].

Farmers are encouraged to conduct accurate land surveys using Eye Level Detectors before leveling to ensure precision and long-term benefits. Without prior knowledge of the land's low and high elevation points, proper leveling cannot be achieved even with a laser land leveler, leading to poor seed germination, lower yields, and wastage of fuel and time. In this regard, an instrument called the Eye Level Detector is provided with a complete set of a laser land leveler, which can be used for land surveying. For ease of use, farmers can follow a simple method to conduct the survey: first, turn on the Eye Level Detector and the transmitter at a corner of the field, and take the initial reading. Subsequently, record readings at intervals of 20 steps across the one-acre field. This process results in approximately 109 readings per acre. The average of these readings should then be calculated. This average value indicates the point where the blade of the laser land leveler should be manually set. After adjusting the blade accordingly, the tractor should be operated in circular paths without lifting or adjusting the blade repeatedly. When the blade stops scooping or pushing soil, it indicates that the land has been leveled properly.

2.2. Methods of Wheat Sowing

In Sindh province, farmers generally sow wheat using two methods: (i) *Ghurbi sowing method* – a traditional technique involving broadcasting seeds onto wet soil, which allows water to percolate deeply after soaking; and (ii) *Wat Khair* sowing method broadcasting seeds after ploughing the soil with optimal moisture for proper seed germination, followed by light ploughing with a cultivator to cover the seeds. These techniques have several disadvantages, including poor seed germination, higher water consumption, and comparatively lower yields. In contrast to that, wheat produces 22% higher yield with ridge planting [4], 16.4% higher yield with raised bed planting [5] and 9% higher yield with the drill method [6] over that of the conventional broadcasting method. Therefore, these techniques need to be disseminated among the farming communities for its wide scale adaptation.

For ridge sowing, after ploughing with a mould board, disc harrow, and cultivator, seed and fertilizer are broadcasted, and then ridges are formed with a ridge maker implement. A large portion of the seed and fertilizer settles on the ridges, where germination of wheat seeds takes place. Irrigation should be applied up to three-fourths the height of the furrow; 75% of the ridge (from bottom to surface) should be irrigated. However, to achieve full seed germination and a good yield, an alternative method involves first developing the ridges, then applying irrigation. Once the gravitational water percolates (usually after 3 to 4 hours of irrigation), the soil remains saturated. Subsequently, wheat seeds, soaked in water for two hours, are broadcasted on the furrows and ridges. This method also helps save water and produces an optimal, good yield.

Wheat sowing on raised beds is carried out using a raised bed planter, which in a single pass creates three furrows and two beds simultaneously. This method significantly conserves irrigation water, results in a 16.4% higher yield [5], and achieves high water use efficiency, measured as seed production in kilograms per cubic meter of water used. The author's experience indicates that wheat yields could be further increased by drilling a single row of wheat seeds into each furrow, excluding sowing on top of the beds.

Drill sowing is also important as wheat produces 9% higher yield [6] over that of the conventional broadcasting method. For drill sowing, depending on the wheat variety, different row spacings have been suggested. For instance, Hussain et al. [7] observed higher wheat yield (Inqilab 91 variety) with cross drill sowing (30×30 cm^2). Planting of low tillering dwarf cultivar (Triple Dwarf-1: TD-1) in narrow (15 cm) rows and low tillering cultivar (Sahar-2006: SH-06) in medium rows (20 cm) results in more productivity owing to a substantial rise in fertile tillers [8]. Farmers are encouraged to consult local agricultural extension departments to select appropriate varieties and ensure proper row spacing, thereby maximizing yield potential.

In the older designs of the wheat drill machine, sowing tines are fixed with a spacing of 6 inches (15 cm) between two consecutive tines, which in turn leads to some soil material being deposited on the middle row between the two consecutive rows. Consequently, this results in reduced seed germination. In such cases, farmers who use a 6-inch tine spacing (15 cm) drill should increase the seed rate by 5-10% to ensure proper plant population. For drill sowing, a seed rate of 175 kg/ha (70 kg of seed per acre) is recommended for the Pak-81 variety of wheat [6]. The seed rate widely depends upon the production of tillers per plant. Therefore, a proper seed rate should be followed when cultivating high- or low-tillering varieties. It is very important to calibrate the raised bed planter and drill machines before use; otherwise, the desired benefits in terms of water saving and yield improvement will not be achieved.

2.3. Planting Time

Timely sowing of wheat is of great importance. Every effort should be made to sow the crop on time to achieve a better yield. Delayed sowing of wheat can lead to a reduction in yield ranging from 8.3% to 63.85%. Specifically, if wheat is sown after November 10 and up to December 25, with a seed rate of 125 kg/ha, the potential yield will be significantly affected. Proper planning and adherence to sowing schedules are essential to maximize productivity and ensure optimal crop development [9]. Sowing time and seed variety have a significant impact on wheat yield. There is a need to have proper knowledge about the interactive effects of seed varieties and sowing time on wheat yield. Research on the national level (Table 1) regarding the varietal performances in relation to different sowing times (three different sowing times) under drill sowing method shows that the varieties Sarsabz, Kiran, Khirman, SKD-1, NIA-Sarang, TD-1, TJ-83, Sassui, NIA-Amber and Bakhtawar produce higher yield at early sowing date, escaping thermal stress and disease infestation [10].

Table 1. A comparison of seed weight per plant as affected by different planting times.

Varieties	Seed weight/Plant (Gram)		
	Early sowing (November 8)	Normal sowing (November 25)	Late sowing (December 10)
Sarsabz	18.9	15.4	8.5
Kiran	24.1	16.5	12.2
Khirman	25.6	16.5	11.8
SKD-1	16.9	12.5	8.9
NIA – Sarang	23	15.7	11
TD – I	16.2	12.9	10.9
TJ – 83	22.6	14.8	10.3
Sassui	19.2	14	10.2
Nia – Ambar	26.9	15.7	12.5
Bakhtawar	21.9	13.4	11.4

Source: Channa, et al. [10].

2.4. Weed Management in Wheat

The sowing method significantly impacts weed emergence. Weed growth is typically higher under conventional cropping systems because the entire soil surface is flooded with irrigation water, which is applied frequently. Unmanaged weed growth can severely reduce wheat yields if not addressed in a timely and effective manner. In Pakistan, inadequate weed control practices or continuous weed growth result in substantial annual yield losses in wheat, ranging from 17% to 25% [11]. Herbicides have a strong effect on weed populations. The application of Isoproturon 50 WP at a rate of 1.0 kg of active ingredients per hectare during post-emergence produces maximum weed control efficiency (84%), the highest number of tillers per square meter (250), and improved wheat yield [12, 13]. Broad-spectrum herbicides, particularly carfentrazone ethyl ester combined with isoproturon, reduced weed density by 93% and 95%, respectively, and also resulted in high seed yield [12, 13].

2.5. Balanced Fertilizer Application in Wheat

To achieve the yield potential of wheat, the proper use of fertilizers is extremely important. According to the NDFC report, balanced fertilizer application can boost wheat production by 70 percent [14, 15]. Research in Punjab, Pakistan, suggests that the application of 6 tons per hectare (2.5 tractor trolleys per acre) of poultry manure, combined with 128–114–62 kg/ha of NPK fertilizer, or the application of farmyard manure during land preparation (before soaking dose) at a rate of 10 tons per hectare (4 tractor trolleys per acre), produces the highest wheat grain yield [16]. Wheat production is often affected by imbalanced fertilizer use. Besides the type and quantity of fertilizer, the method of crop cultivation and fertilizer application also play significant roles. Water is applied to crops through the inundation of agricultural fields using conventional irrigation techniques. As a result, a substantial amount of water along with nutrients is lost due to deep percolation. Consequently, this leads to an increase in the water table, deterioration of groundwater quality, and the movement of groundwater towards river systems through the base flow system. This process transports residual fertilizers, pesticides, and other toxic elements into the water system, thereby degrading water quality in river streams and adversely affecting lower riparian zones and aquatic life [17]. Therefore, water must be applied judiciously so that a major portion of nutrients and fertilizer remains within the crop root zone. The recommended NPK fertilizer levels for major wheat varieties of Sindh are provided in Table 2. These recommended NPK levels are for wheat cultivation in fertile soil; however, the rate of NPK fertilizers could be increased if the soil has a low NPK concentration. Nevertheless, fertilizer application should always be guided by soil testing to tailor nutrient doses to field conditions and prevent leaching losses.

Table 2. Recommended NPK levels for major wheat varieties.

Variety	Nitrogen (Urea) kg/acre	Phosphorus (DAP) kg/acre	Potash (SOP) kg/acre	Source
TD – 1	50	25	25	Laghari, et al. [18]
TJ – 83	75	25	25	
MEHRAN – 89	75	25	25	
NIA – SUNDAR	61	45	-	Khan, et al. [19]
NIA – MB – 2	49	37	25	Abbas, et al. [20]
SARSABZ	49	25	25	Lashari, et al. [21]
KIRAN – 95	49	25	25	
KHIRMAN	49	37	25	Khan, et al. [22]
NIA-SARANG	49	37	25	Phullan, et al. [23]

2.6. Irrigation Schedule

The application of irrigation water exceeding the wheat crop's water requirement not only wastes water but also causes the leaching of valuable nutrients from the crop's effective root zone. This leaching results in poor crop growth and reduced yield. Additionally, excessive irrigation can lead to increased water table depths, causing waterlogging and salinity issues. These conditions deteriorate groundwater quality due to residual fertilizers and other unwanted toxic elements, further impacting crop health and environmental sustainability [17]. Therefore, the knowledge of crop water requirement is necessary for efficient management of water resources, particularly when shallow water table depths (≤ 2.00 m) are expanding on a considerable land area. In this Sindh province, shallow WTDs (≤ 2.00 m) covering 28% to 69% of the canal command area pre and post monsoon seasons [24]. The shallow water table depth (≤ 2.00 m) are the potential resource that can be utilized to meet the crop water requirements through sub surface irrigation by adapting the proper irrigation scheduling [25]. The research studies conducted by PCRWR in Sindh indicate that the wheat variety NIA – SARANG requires 480 millimeters of water, with a 25% groundwater contribution, at a water table depth (WTD) managed at 1.5 meters. The irrigation schedule developed for this wheat variety involves five irrigations (excluding the soaking dose), each delivering 75 mm of water, with an interval of 21 days between irrigations.

Notably, the water depth for the fourth irrigation should be increased to 90 mm. Additionally, the water depth for the soaking dose should be 100 mm to ensure optimal growth and yield [26]. Water requirement for wheat in central Punjab is 421 mm [27].

2.7. Control Of Root Rot, Loose Smut, Black Point and Leaf Rust Diseases

Fungal diseases pose a potential threat to successful wheat production in Pakistan. In Pakistan, stem rust, leaf rust, loose smut, and leaf blight are reported to be the most damaging diseases of wheat, causing a decline in yield of up to 50% [28]. The research studies in Sheikhupura, Punjab, Pakistan suggest that the fungicides Tubeconazol + Imidachloprid (Hombare @ 4 ml/kg of wheat seed) and Difenoconazol + Cyproconazol (Dividend Star @ 1 ml/kg of wheat seed) exhibit the best results in reducing the incidence of root rot, loose smut, and black point disease [29].

The severity of rust is closely related to varietal selection, fertilizer rate and time of sowing. Early sowing on October 30 with 80:70:63 kg/ha of NPK has paramount importance to combat leaf rust severity effectively [30]. Fungicide applications between the full elongation of the flag leaves and anthesis typically result in greater reductions in disease severity and increases in wheat output or grain quality. A research study conducted in Hyderabad, Tando Muhammad Khan, and Thatta districts of Sindh shows that among fungicides, Tilt and Bloom are the most effective in controlling leaf rust, which reduces rust severity by up to 5% compared to the control, which exhibits 100% severity [31]. The appearance and distribution of leaf rust exhibit different patterns at various sowing times under natural field conditions (Table 3).

Late-planted varieties suffer the highest disease infestation due to disease epidemics compared to early planting. The TD – 1 variety is susceptible to leaf rust when sown early, while most other varieties are moderately susceptible. Among these ten varieties, Bakhtawar and Sassui are resistant to rust. The varieties SKD – 1 and TJ – 83 are moderately susceptible to rust [10].

Table 3. Leaf rust appearance and distribution observed at three different sowing times under natural field conditions.

Wheat variety	Early sowing (08 Nov)	Normal sowing (25 Nov)	Late sowing (10 Dec)
SARSABZ	30 MS	60 MS	70 MS
KIRAN-95	20 MS	50 MS	70 MS
KHIRMAN	30 MS	50 MS	60 MS
SKD-1	30 MS	50 MSS	60 MSS
NIA-SARANG	20 MS	40 MS	60 MS
TD-1	50 S	80 S	80 S
TJ-83	40 MS	50 MSS	70 MSS
SASSUI	10 R	10 R	20 R
NIA-AMBER	10 MS	30 MS	40 MS
BAKHTAWAR	05 R	10 R	20 R
MORROCO	80 S	100 S	100 S

Note: Leaf rust data has two parts, first is severity percentage according to modifies Cobb's scale and second is response to infection; R = Resistant, MR = Moderately resistant, MS = Moderately susceptible, MSS= moderately susceptible to susceptible and S = Susceptible.
Source: Channa, et al. [10].

3. Conclusions

Pakistan's wheat productivity challenge is not merely an agronomic issue; it is a matter of national food security and rural resilience. The persistent yield gap, despite decades of research and technological progress, reflects a systemic need for integrated and adaptive management. Sustainable intensification of wheat production requires a holistic strategy that combines science-driven agronomy with farmer-centered implementation. Optimized land preparation through laser leveling, precision sowing, and timely planting are foundational to maximizing resource use efficiency and improving plant establishment. Balanced fertilization, guided by soil testing and integrated nutrient management, can restore soil health and sustain productivity, while efficient irrigation scheduling ensures that every drop of water contributes directly to yield. Equally, proactive disease management and integrated weed control are indispensable for maintaining crop vigor and minimizing losses. The success of these practices, however, depends on strong extension services, farmer education, and timely access to quality inputs. Strengthening institutional coordination between research, policy, and field-level operations will be essential to closing the yield gap sustainably. By embracing precision agriculture, resource efficiency, and climate-smart practices, Pakistan can move closer to realizing the full potential of its wheat sector, ensuring food security, economic stability, and a resilient agricultural future for millions who depend on this vital crop.

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