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RESEARCH ARTICLE

Impact of tillage methods and cultivars on phenology & productivity of wheat-rice system under irrigated conditions

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Abstract

The research was conducted at the Agricultural Research farm of the Agronomy Department at Palampur, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya (CSK HPKV) and Rice and Wheat Research Center (RWRC) Malan, Himachal Pradesh to study the impact of tillage methods & crop species on phenology & production of wheat-rice crops under irrigated conditions. The study's basic premise was to identify wheat and rice cultivars that can perform well under specific tillage options. The trial was conducted from the winter 2019 to the rainy season of 2021, using a split-plot design. Four tillage methods- zero tillage, conventional tillage, natural farming and reduced tillage- were tested on three species of rice (HPR 2656 (*Him Palam Dhan* 1), HPR 2795 (*Him Palam Dhan Lal* 1) & HPR 1156 (*Sukara Dhan Lal* 1) and three species of wheat (HPW 368 (*Him Palam Gehun* 2), HS 562 (*Central wheat*) & HPW 349). The results showed that in both crops, traditional farming (conventional tillage) methods were more efficient than other methods in terms of crop yield.

Conversely, the lowest grain yields were observed with natural farming for both crops. Specifically, the adoption of zero tillage, natural agriculture, and reduced tillage results in wheat grain yield reductions of 10.9%, 4.6%, and 59.4%, respectively, compared to conventional tillage. Similarly, rice grain yields declined by 10.8%, 34.0%, and 16.1% with zero tillage, natural farming and reduced tillage, respectively, compared to conventional tillage. Among the cultivars evaluated, HPW 368 for wheat and HPR 2795 for rice produced significantly higher grain yields at both locations over the two years. The findings of the present investigation would help the wheat and rice growers identify suitable cultivars that would be economically grown with varying tillage options and under natural farming conditions.

Keywords

conventional tillage; cultivars; reduced tillage; rice; wheat

Introduction

Wheat and rice are the two major food crops cultivated in almost all the states of India, with the rice-wheat cropping system being the most common of the 30 central agricultural systems recognized globally. Wheat is grown mainly as an irrigated crop in more than 90 % of the area under its cultivation, though the area under rainfed conditions is also significant. Also, about 40 % of the rice cultivated in India depends on rain for its production, with both lowland rainfed and upland rainfed systems practised. The agricultural production system is the largest and most advanced in the world. In Asia, this production system is practised on 13.5 M ha, 57% of which are in South Asia (1). The majority of the Indo-Gangetic Plains are located in this area. The rice-wheat production system in India uses 9.2 M ha (2), which significantly increases the country's capacity to feed its people in times of need. India grows wheat on 31.45 M ha and harvests 107.59 Mt with an average harvest of 3420 kg ha^{-1} (3), whereas rice is planted on 43.78 M ha and harvests 118.43 Mt (3), with an average harvest of 2705 kg ha^{-1}. However, the productivity of both these crops varies significantly between irrigated and rainfed conditions. The average productivity of wheat under irrigated conditions in India exceeds 4000 kg ha^{-1}, while the productivity under rainfed conditions exceeds 200 kg ha^{-1}. Similarly, rice productivity under irrigated transplanted conditions ranges between 4000-6000 kg ha^{-1}, while it is limited to about 2000 kg ha^{-1} under rainfed upland conditions.

Traditional tillage methods are simple and generate a clean and neat growing environment. For a long time, they were used to produce a cultivar of crops, including wheat and rice, but they are now thought to be labour and fuel-intensive processes. Significant erosion risk exists with conventional tillage. The soil is completely inverted, and agricultural waste and residue are buried, making the land vulnerable to the erosive influences of water and wind (4, 5). Long-term erosion has an impact on the production of the soil. All of these difficulties can be resolved with conservation tillage (6).

In recent years, Conservation Agriculture (CA) technologies have gained popularity as farmers aim to reduce variable cultivation costs, primarily due to the high energy consumption associated with crop planting and soil preparation. By performing tillage operations with reduced intensity, these goals can be achieved. Among these methods, Zero tillage (ZT), a practice in which both primary and secondary tillages are avoided, and only a tiny furrow opened up to put the fertilizers and seed, has proven to be more viable, energy efficient and environmentally friendly compared to traditional sowing practices (7). Similarly, reduced tillage practices in which only primary tillage is practiced while avoiding secondary tillage besides retaining a portion of the residue of the preceding crop have also gained popularity. By utilizing the remaining moisture in the soil, minimal and no-tillage systems can ensure timely planting and successful germination, reducing the price of production. Also, the concept of natural farming is being promoted among the farming community, which focuses on the use of inputs that can be prepared on the farm without having to depend on external sources with the object of reducing the cost of cultivation besides avoiding the use of hazardous agrochemicals (4, 5).

The performance of rice and wheat genotypes can differ significantly due to various factors, including the tillage practices employed and the effects of changing environmental conditions that can have a bearing on the optimum planting window with the adoption of CA (8). Furthermore, specific genotypes are recommended in different regions globally for no-till farming. However, in India, limited research has been conducted to identify different cultivars of wheat and rice suitable for CA practices. Consequently, it is essential to research this novel idea in one of the most significant grain crops produced in the state. The proposed study was conducted to identify potential cultivars that can perform well under varying tillage treatments. Another focus of the study was to identify rice and wheat cultivars suited to adopting natural farming practices.

Materials and Methods

Experiment sites and conditions of weather

The research was conducted for two years at the Agricultural Research Farm of Agronomy Department (32°07' N latitude, 76°23′ E longitude) and RWRC, Malan (32°07' N latitude, 76°23′ E longitude), Himachal Pradesh, India spanning from *Rabi* 2019 to *Kharif* 2021. A sub-temperate humid climate, mild summers, and harsh freezing winters with sporadic rainfall characterize both sites.

Palampur:

During the wheat growing season, the lowest weekly temperature for 2019-20 was observed in 52 and 1 standard weeks (Fig. 1 & 3), while in the subsequent year, 2020-21, it occurred during 51 and 52 standard weeks. During both years of research, the highest weekly temperature was recorded from 15 to 17 standard weeks. May exhibited the highest average relative humidity during both wheat growing seasons, while December saw the lowest relative humidity. At both locations, during the wheat growing season, the crop received a consistent rainfall of 107.8 mm and 68.6 mm in 2019-20 and 2020-21 (Fig. 1 and 3). In contrast, during rice development seasons, the lowest temperature was recorded during 43 and 44 standard weeks (Fig. 1 & 3) and during rice growth seasons, July reported the highest weekly temperature. Further, the month of July (22 and 34 standard weeks) observed higher average relative humidity, while lower relative humidity was followed in November (41-44 standard weeks). During rice growth seasons in 2020 and 2021, the crop received a total rainfall of 226.8 and 559.0 mm, as indicated in (Fig. 2 and 4).

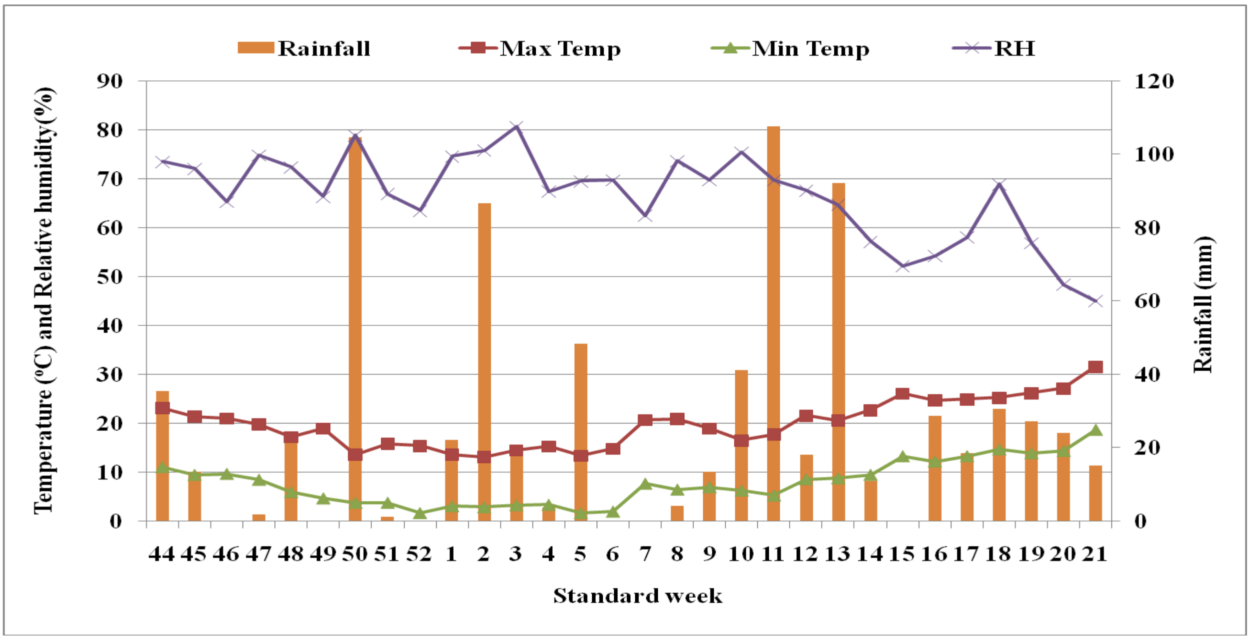


Fig. 1. Meteorological data at Palampur during November 2019 to May 2020

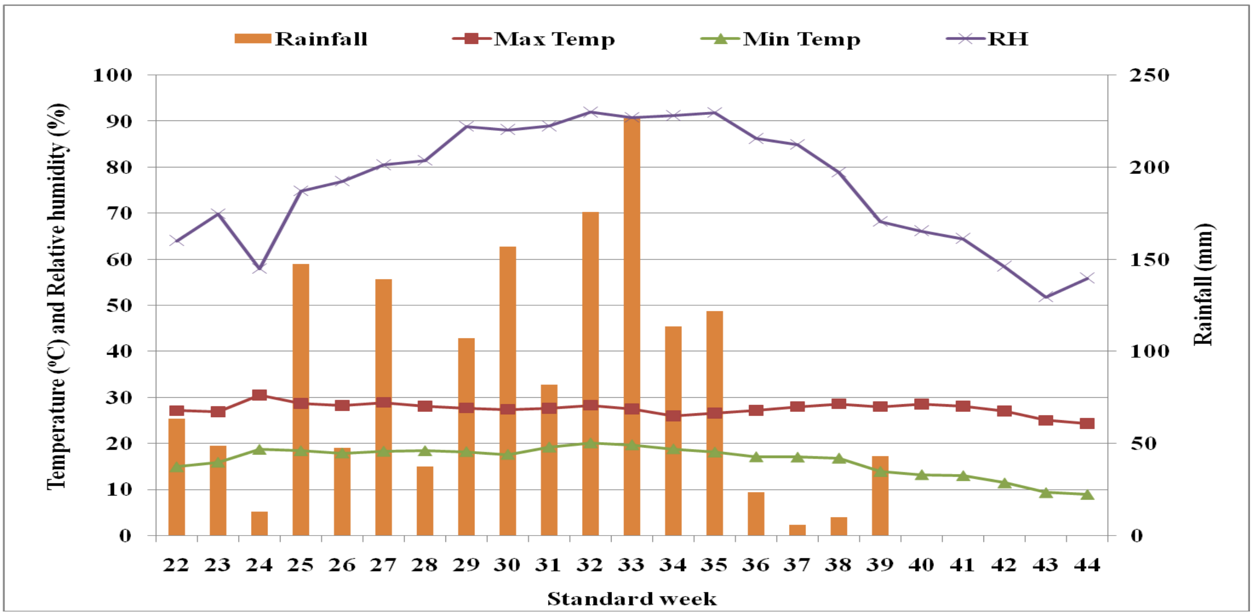


Fig. 2. Meteorological data at Palampur during June 2020 to October 2020

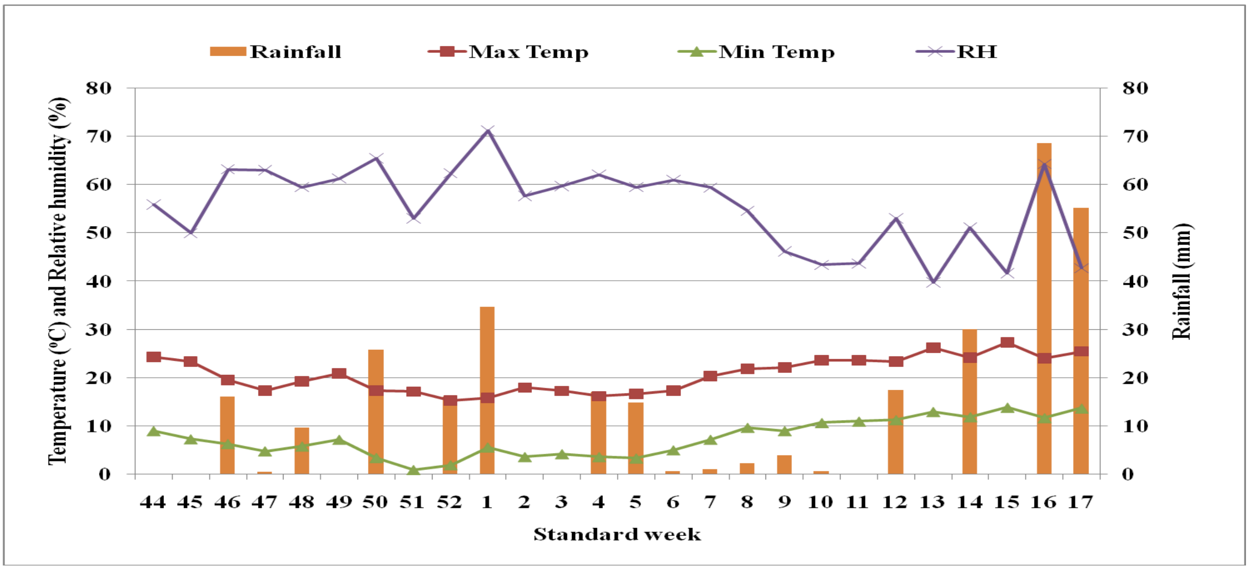


Fig. 3. Meteorological data at Palampur during November 2020 to May 2021

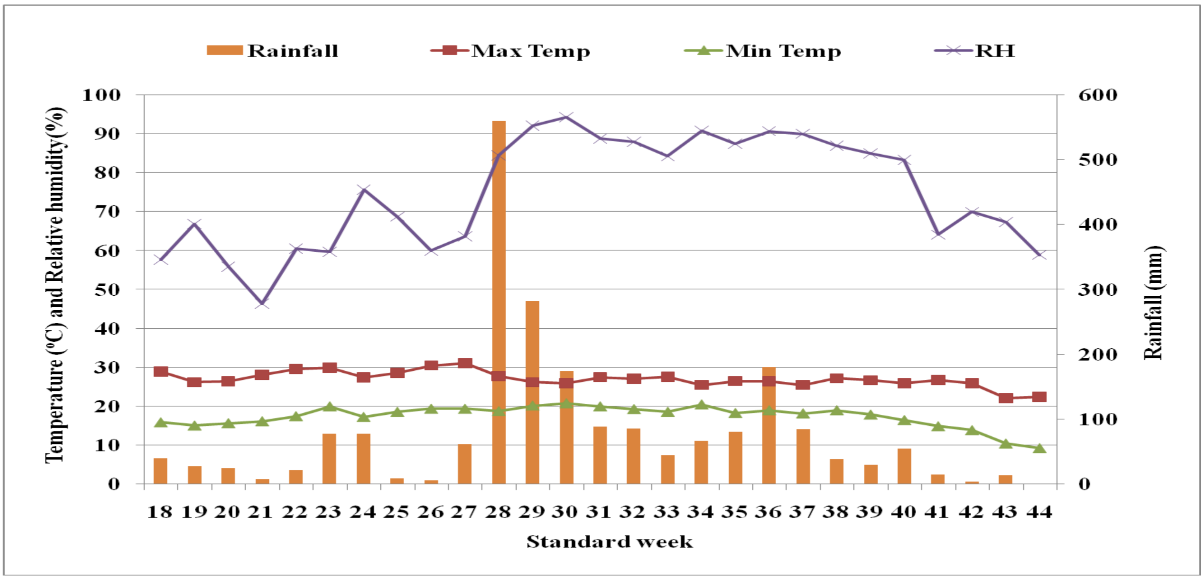


Fig. 4 Meteorological data at Palampur during June 2021 to October 2021

Malan:

During the wheat growing season, the lowest weekly temperature for 2019-20 was observed in 1 and 2 standard weeks (Fig. 5 & 7), while in the subsequent year, 2020-21, it occurred during 51 and 52 standard weeks. During both years of research, the highest weekly temperature was recorded from 15 to 17 standard weeks. May exhibited the highest average relative humidity during both wheat growing seasons, while December saw the lowest relative humidity. At both locations during the wheat growing season, the crop received a consistent rainfall of 107.8 mm and 68.6 mm in 2019-20 and 2020-21 (Fig. &). In contrast, during both seasons of rice development, the lowest temperature was recorded during 41 and 42 standard weeks (Fig. 5 and 7) and rice growth seasons in July reported the highest weekly temperature. Further, July (33 standard weeks) observed higher average relative humidity, followed by lower relative humidity in November (41-42 standard weeks). During rice growth seasons in 2020 and 2021, the crop received a total rainfall of 226.8 and 559.0 mm, as indicated in (Fig. 6 & 8). Nitrogen, phosphorus, and potassium content of the experimental site were determined by Micro-Kjeldahl's method (9), ascorbic acid blue colour method (10), and flame photometer method (11), respectively. The soil was silty loam in texture and exhibited medium levels of available potassium, organic carbon, phosphorus and nitrogen (Table 1).

Experimental design and management of crop

The research was laid out in a split-plot design to study the interaction between the tillage options and cultivars and identify variety (ies) suitable for zero tillage, reduced tillage, or natural farming. The main plot featured four different tillage methods: conventional tillage (CT), natural farming (NF), zero tillage (ZT) and reduced tillage (RT). Three distinct crop species, rice and wheat, were planted in each sub-plot of the main plots. The experiment included 12 treatment combinations per replication, replicated three times at each location (Table 2). The cultivars of wheat selected for the present investigation include HPW 349, HPW 368 and HS 562, all three cultivars being recommended for timely sown conditions (44-47 standard meteorological weeks) in the Northern hill zone of the country. All these three cultivars are high-yielding varieties and are resistant to most of the diseases infesting wheat crops in the region.

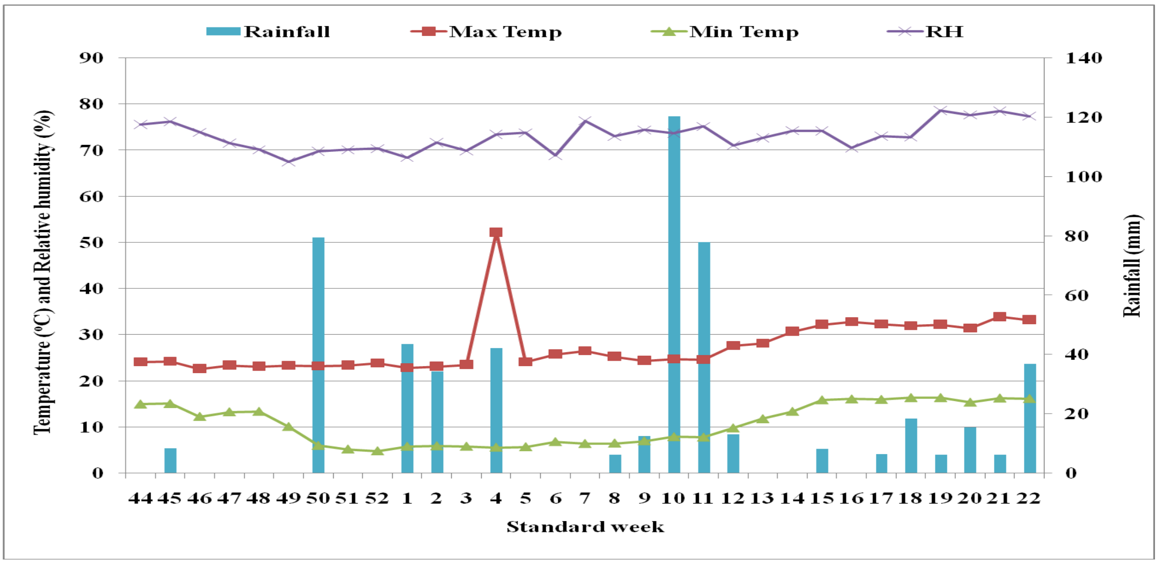
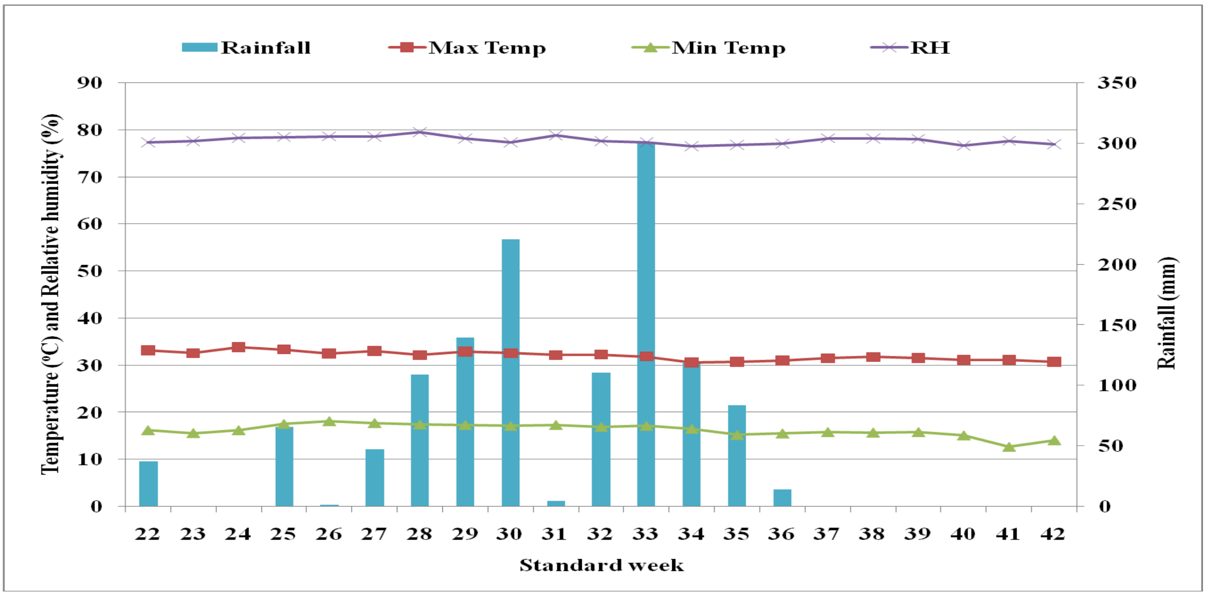


Fig. 5. Meteorological data at Malan during November 2019 to May 2020



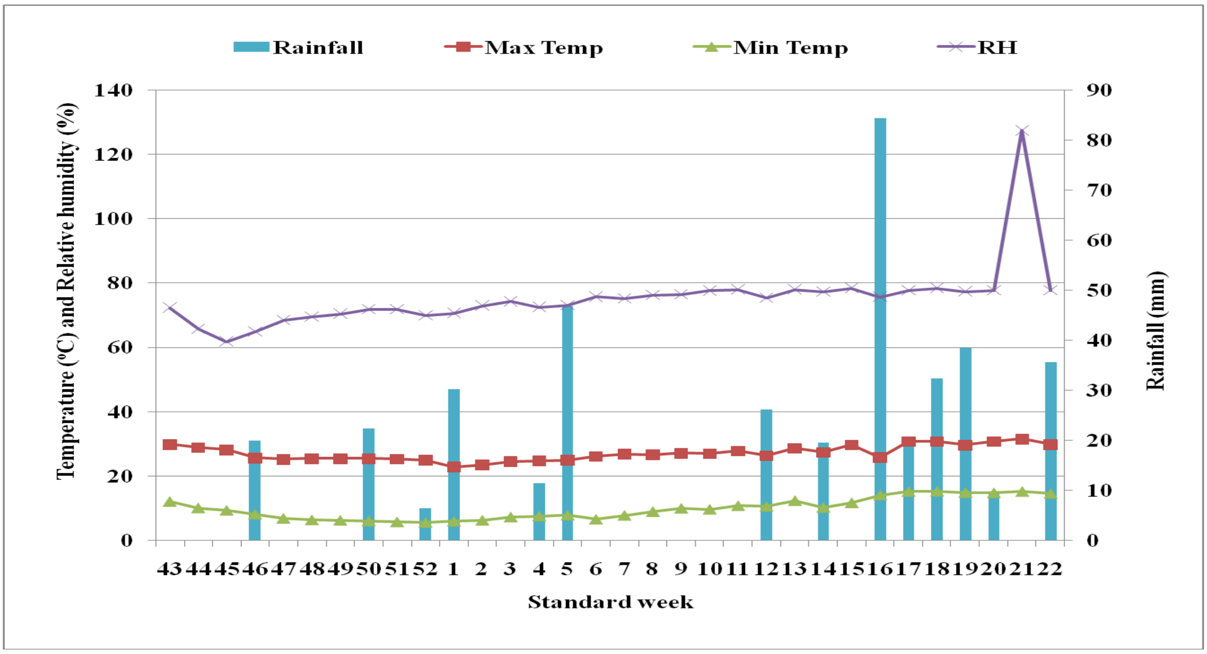


Fig. 7. Meteorological data at Malan during November 2020 to May 2021

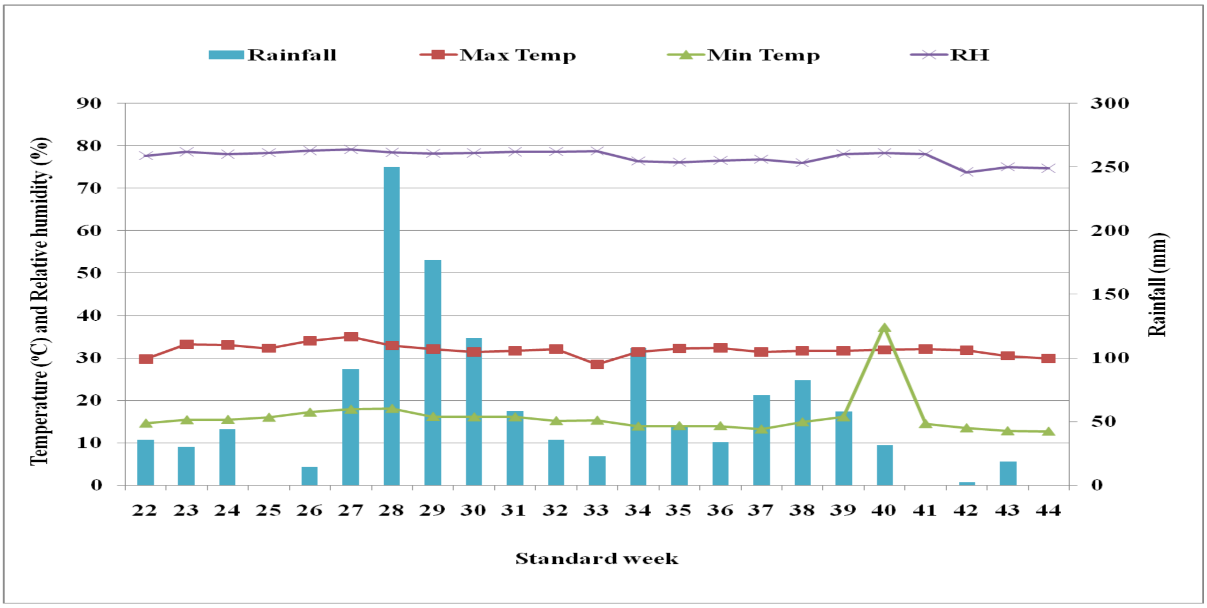


Fig. 8. Meteorological data at Malan during June 2021 to October 2021

Table 1. Physico-chemical soil characteristics (0-15 cm depth)

Particular	Palampur	Malan
Soil	Silty clam loam	Silty clam loam
pH	5.6	5.7
Organic Carbon (OC)	11.0 g kg^{-1}	10.2 g kg^{-1}
Available Nitrogen (N)	376.3 kg ha^{-1}	422.0 kg ha^{-1}
Available Phosphorus (P)	16.4 kg ha^{-1}	17.8 kg ha^{-1}
Available Potassium (K)	276.4 kg ha^{-1}	232.6 kg ha^{-1}

Similarly, the cultivars selected for rice (HPR 1156, HPR 2656 and HPR 2795) are recommended for dry-seeded rice cultivation in the state. Both sites followed standard sowing dates and recommended practices for cultivating wheat and rice crops, maintaining a spacing of 20 cm between rows. The inorganic fertilizers urea, SSP, and MOP were applied to all plots, except for those where natural farming was practised, at 60:30:30 and 120:60:40 kg NPK ha^{-1} for rice and wheat. Phosphorus and potassium were entirely delivered at sowing time, while nitrogen was applied in two equal portions during the planting and tillering stages. Before planting, glyphosate/paraquat was applied on plots with zero tillage. In the wheat fields, weeds were managed using Vesta (a combination of clodinafop propargyl and metsulfuron-methyl) applied @ 400 g per hectare. In the rice fields, weeds were controlled by applying butachlor @ 1.5 kg per hectare. In natural farming treatment, weeds were removed manually in the subsequent crop. The natural farming treatment followed all the recommended practices for this cultivation method.

To measure the biological yield, wheat and rice crops were collected from designated plots and dried for several days before being weighed. The harvested grains then underwent a threshing process, after which the obtained grains were cleaned thoroughly and grain weight was duly noted. The harvested yield was subtracted from the total biological yield to determine straw yield. All yield measurements from the respective net plots were converted to q ha^{-1} for standardization.

The data about the appearance of different phenophases of wheat and rice crops under different treatments were recorded. The plots were visited regularly to observe the emergence of spikes or panicles after the booting stage. Once 50% of the spikes or panicles had emerged in the plot, the corresponding date was recorded, and the duration until 50% flowering was calculated from the sowing date. Subsequently, when 85% of the plants within each plot exhibited a golden yellow hue, and their grains demonstrated resistance to crushing with nails, they were meticulously assessed for harvesting readiness. The date of achieving adequate grain hardness was documented and the period required for maturity was determined from the sowing date.

The Gomez & Gomez approach (1984) (12) was used to analyze the data statistically. For parameters having substantial influence at the 5% probability level, the critical difference (CD) was computed.

Results and Discussion

Tables 3 and 4 present empirical findings concerning the impact of various agricultural treatments on wheat and rice cultivars yield outcomes across consecutive years at Palampur and Malan (Fig. 9, 10, 11 and 12). The data analysis indicates a significant influence of tillage practices and crop cultivars on the grain yield, straw yield and overall biological yield of wheat and rice. Throughout the study period, CT consistently provided the highest seed yield (Palampur-44.80, 44.58; Malan-48.25, 45.03), showing statistical equivalence to RT (Palampur-43.34, 42.03; Malan -46.78, 42.29) practices in both years. Conversely, natural farming methods (Palampur-16.80, 16.11; Malan-19.79, 21.64) consistently produced the lowest grain yields. The superior performance of conventional tillage in terms of grain yield can be attributed to enhanced values across all yield parameters. The flexibility of soil under conventional tillage facilitates optimal root development, thereby improving nutrient absorption and subsequent crop productivity.

Table 2. Treatment combinations

Treatments		
Main plot factor	**Sub-plot factor**	
Reduced tillage	**Wheat**	**Rice**
Zero tillage	HPW 349	HPR 1156 (*Sukara Dhan* 1)
Conventional tillage	HPW 368 (*Him Palam Gehun* 2)	HPR 2656 (*Him Palam Dhan* 1)
Natural farming	HS 562 (*Central wheat*)	HPR 2795 (*Him Palam Lal Dhan* 1)
Treatment Combinations		
Treatment	**Wheat**	**Rice**
T_1	Reduced tillage + HPW 349	Reduced tillage + HPR 1156
T_2	Reduced tillage + HPW 368	Reduced tillage + HPR 2656
T_2	Reduced tillage + HS 562	Reduced tillage + HPR 2795
T_4	Zero tillage + HPW 349	Zero tillage + HPR 1156
T_5	Zero tillage + HPW 368	Zero tillage + HPR 2656
T_6	Zero tillage + HS 562	Zero tillage + HPR 2795
T_7	Conventional tillage + HPW 349	Conventional tillage + HPR 1156
T_8	Conventional tillage + HPW 368	Conventional tillage + HPR 2656
T_9	Conventional tillage + HS 562	Conventional tillage + HPR 2795
T_{10}	Natural farming + HPW 349	Natural farming + HPR 1156
T_{11}	Natural farming + HPW 368	Natural farming + HPR 2656
T_{12}	Natural farming + HS 562	Natural farming + HPR 2795

Table 3. Impact of tillage methods on yield (q ha^{-1}) of different wheat Cultivars

Treatments	Palampur						Malan					
	Grain yield		Straw yield		Biological yield		Grain yield		Straw yield		Biological yield	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
Tillage methods												
Reduced Tillage	43.34	42.03	62.27	58.74	105.61	100.77	46.78	42.29	70.58	61.66	117.36	104.35
Zero Tillage	40.00	39.88	58.86	56.75	98.87	96.64	43.86	39.18	69.22	58.27	113.08	97.45
Conventional	44.80	44.58	62.91	62.23	107.71	106.81	48.25	45.03	70.84	63.01	119.08	108.04
Natural farming	16.80	16.11	26.88	25.05	43.68	41.16	19.79	21.64	32.87	34.11	52.65	55.74
SEm ±	1.02	1.03	1.57	1.05	2.57	2.03	0.93	0.94	1.74	1.47	2.59	2.44
CD (P = 0.05)	2.50	2.53	3.84	2.58	6.29	4.97	2.29	2.40	4.27	3.59	6.34	5.98
Cultivars												
HPW 349	34.88	34.07	50.55	48.36	85.43	82.43	37.43	35.01	58.48	51.31	95.91	86.33
HPW 368	37.25	37.02	54.87	53.42	92.12	90.44	41.74	39.25	65.92	59.44	107.66	98.69
HS 562	36.58	35.87	52.77	50.30	89.35	86.17	39.84	37.13	58.22	52.03	98.06	89.17
SEm ±	0.63	0.44	0.70	0.73	1.23	1.13	1.05	0.91	1.59	1.62	2.49	2.47
CD (P = 0.05)	1.33	0.92	1.49	1.54	2.62	2.39	2.22	1.92	3.36	3.44	5.27	5.23

Table 4. Impact of tillage methods on yield (q ha^{-1}) of different rice Cultivars

Treatments	Palampur						Malan					
	Grain yield		Straw yield		Biological yield		Grain yield		Straw yield		Biological yield	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Tillage methods												
Reduced Tillage	30.13	30.68	54.02	54.44	84.15	85.12	30.60	32.13	54.98	56.56	85.59	88.69
Zero Tillage	28.76	29.11	53.26	53.01	82.02	82.12	27.78	30.51	51.22	55.17	78.99	85.68
Conventional Tillage	33.88	34.52	59.73	60.47	93.61	94.99	34.21	35.87	60.13	62.47	94.34	98.34
Natural farming	23.59	19.09	45.19	35.87	63.79	54.96	22.81	26.02	43.26	48.47	66.07	74.50
SEm ±	1.02	0.58	2.12	0.91	3.14	1.46	0.97	0.93	1.71	1.62	2.68	2.54
CD (P = 0.05)	2.51	1.41	5.19	2.22	7.69	3.58	2.38	2.29	4.19	3.97	6.55	6.21
Cultivars												
HPR 1156	28.92	28.31	51.83	49.98	80.75	78.29	28.80	31.26	51.33	54.77	80.13	86.03
HPR 2656	27.59	26.80	51.77	50.39	79.07	77.19	27.05	28.66	51.04	53.76	78.09	82.42
HPR 2795	31.05	29.94	55.56	52.47	86.61	82.41	30.70	33.48	54.82	58.47	85.53	91.95
SEm ±	0.53	1.15	0.99	2.12	1.50	3.25	0.94	0.86	1.70	1.48	2.64	2.33
CD (P = 0.05)	1.13	2.43	2.10	NS	3.19	NS	2.00	1.82	NS	3.14	5.59	4.94

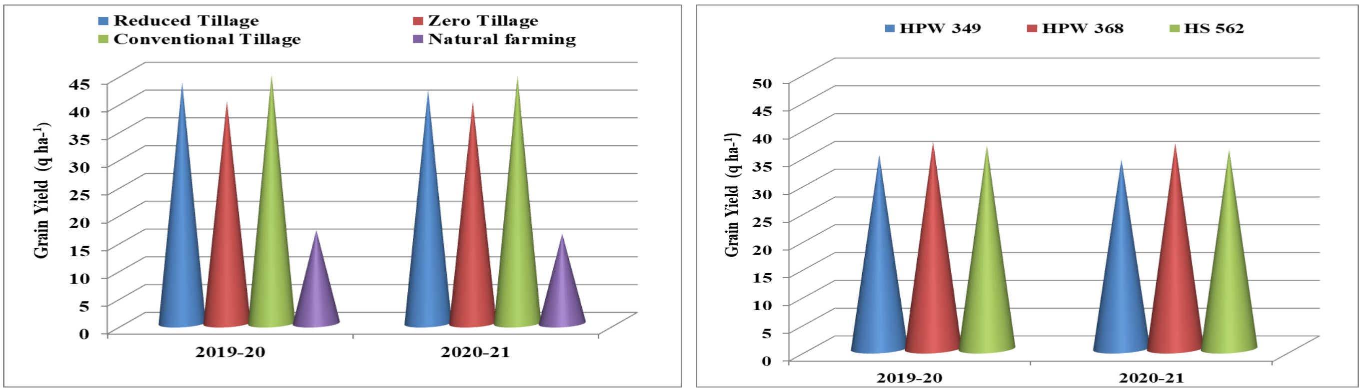


Fig. 9. Influence of cultivars and tillage methods on wheat yield at Palampur

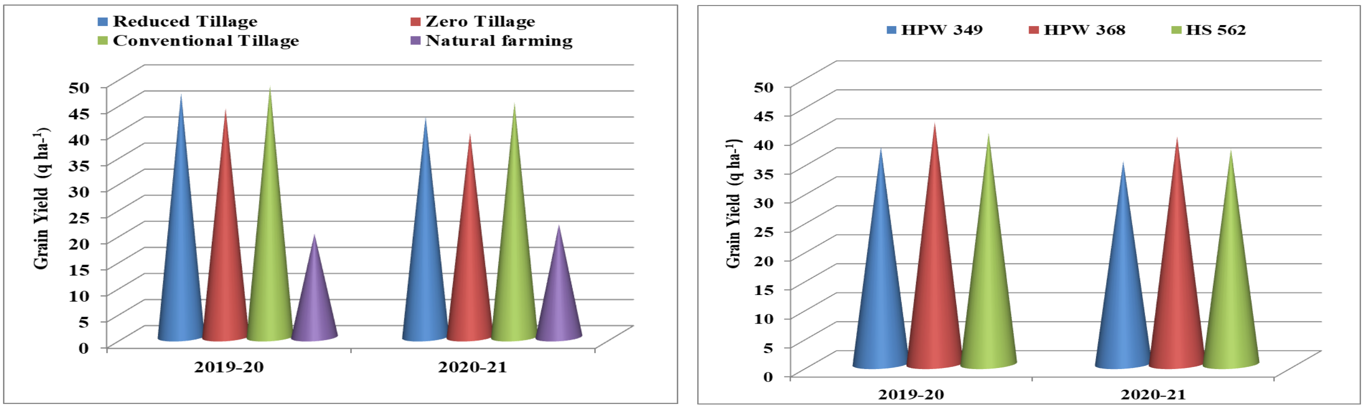


Fig. 10. Influence of cultivars and tillage methods on wheat yield at Malan

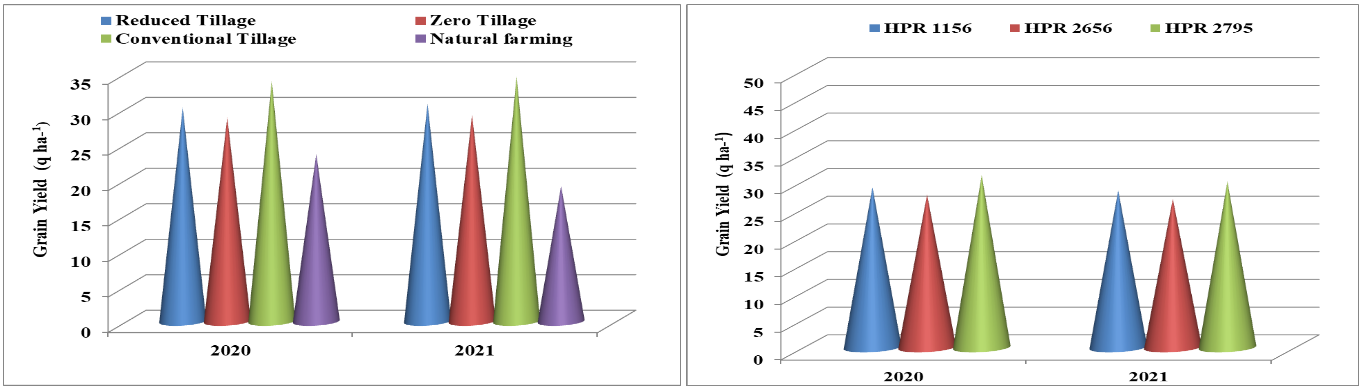


Fig.11. Influence of cultivars and tillage methods on rice yield at Palampur

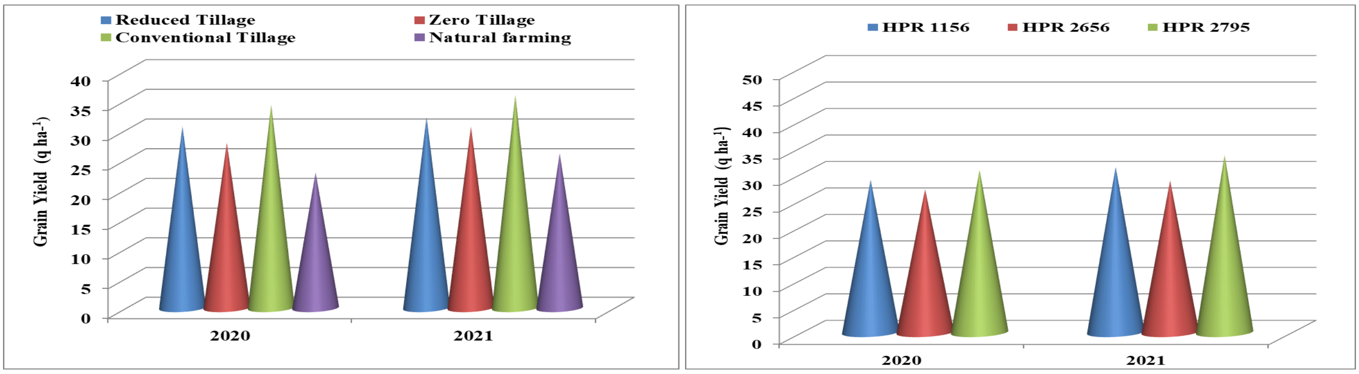


Fig. 12. Influence of cultivars and tillage methods on rice yield at Malan

Conversely, reduced tillage practices leave residue on the soil surface, temporarily storing nitrogen and reducing accessibility during critical growth phases and consequently, slower initial crop development. Additionally, ZT conditions, characterized by poor root aeration, hamper root growth and nutrient uptake, ultimately culminating in diminished grain yields. These observations align with prior investigations conducted by Seth *et al*. in 2018, 2019 and 2020, as well as Saini *et al*. in 2022 and 2024 (13-16 and 27).

Among the cultivars examined, HPW 368 (Palampur-37.25, 37.02; Malan-41.74, 39.25) demonstrated a higher grain yield, whereas HPW 349 (Palampur-34.88, 34.07; Malan -37.43, 35.01) resulted in a reduced grain yield consistently over both years. However, the superior yield in HPW 368 is attributed to the enhanced performance of all crop yield components; in contrast, the lower values of all the yield components in HPW 349 led to its reduced yield.

Tillage methods significantly influenced wheat's biological and straw yield at Malan and Palampur during the crop study period. Conventional tillage led to considerably higher biological (Palampur-107.71, 106.81; Malan-119.08, 108.04) and straw yields (Palampur-62.91, 62.23; Malan-70.84, 63.01) followed by reduced tillage and ZT. The greater straw yield observed with CT can be ascribed to increased nutrient accessibility and uptake and better root development. These factors collectively enhance photosynthetic activity, leading to an increased straw yield. Insufficient nutrient supply resulted in case of natural farming treatment results in lower biological (Palampur-43.68, 41.16; Malan-52.65, 55.74) and straw (Palampur-26.88, 25.05; Malan-32.87, 34.11) yields. The outcomes are consistent with previous research (13-18).

Among the Cultivars examined higher biological (Palampur-92.12, 90.44; Malan-107.66, 98.69) and straw (Palampur-44.87, 53.42; Malan-65.92, 59.44) yield was observed in HPW 368, during the study period of the crop while reduced biological (Palampur-85.43, 82.43; Malan-95.91, 86.33) and straw (Palampur-50.55, 48.36; Malan-58.22, 51.31) yield was reported in case of HPW 349.

Table 4 presents data on the influence of various rice cultivars and tillage methods on grain yield in Malan and Palampur. CT (Palampur-33.88, 34.52; Malan-34.21, 35.87) consistently results in significantly greater grain yield compared to RT and ZT, with natural farming yielding the lowest grain (Palampur-23.59, 19.09; Malan-22.81, 26.02) output across both years of the study. The superior grain yield under CT can be ascribed to enhanced yield attributes and contributing factors. The soil's softening during field preparation under conventional tillage promotes better root growth, enabling more efficient nutrient uptake and supporting better crop growth and yield. In contrast, RT, which leaves residue on the soil, may initially hinder growth due to increased nitrogen immobilization, ultimately lowering yield. These findings align with those of Seth *et al*. (8,13,14), Ankit *et al*. (15) and Saini et al. (20,21).

Among the cultivars studied, HPR 2795 exhibited the highest grain (Palampur-31.05, 29.94; Malan-30.70, 33.48) yield, whereas HPR 2656 recorded the lowest (Palampur-27.59, 26.80; Malan-27.05, 28.66) yield. The yield characteristics of these cultivars can be connected to yield variations, with HPR 2795 consistently outperforming HPR 2656.

During the study period, tillage methods also significantly influenced straw and biological yield at both sites (Malan and Palampur). Conventional tillage led to markedly higher biological (Palampur-93.61, 94.99; Malan-

94.34, 98.34) and straw (Palampur-59.73, 60.47; Malan-60.13, 62.47) yields, followed by RT and ZT. Higher straw yield under CT is likely due to better root development, improved nutrient accessibility and uptake, which enhance plant stand and photosynthetic activity, unlike the lower biological (Palampur-63.79, 54.96; Malan-66.07, 74.50) and straw (Palampur-45.19, 35.87; Malan-43.26, 48.47) yields observed under natural farming. These outcomes are consistent with previous research by Ankit *et al*. (2022c, 2022d) (8, 20). The data further demonstrated that natural farming produced significantly lower biological and straw yields than other methods, primarily due to inadequate availability of nutrients within this system.

Among the cultivars investigated for both years, HPR 2795 recorded substantially higher straw (Palampur-55.56, 52.47; Malan-54.82, 58.47) yield & biological (Palampur-86.61, 82.41; Malan-85.53, 91.95) yield which was following HPR 1156. Significantly lower straw yield (Palampur-51.77, 49.98; Malan-51.04, 53.76) and biological (Palampur-79.07, 77.19; Malan-78.09, 82.42) yield was observed in HPR 2656.

Tables 5 and 6 present data on the impact of various treatments on the days required to reach 50% flowering and physiological maturity in wheat. Analysis indicates that different tillage methods significantly affected the duration of grain achieving physiological maturity and 50% flowering. Wheat ploughed using natural farming practices significantly took more No. of days to reach 50 percent flowering while all other methods were at par. The long growth cycle required for crops under natural farming can result in the slow growth of crops due to insufficient nutrient availability, which further results in poor development and ultimately takes a higher No. of days to reach 50 percent flowering and physiological maturity.

Among the cultivars investigated, 50 percent flowering and physiological maturity was not significantly impacted by the different wheat cultivars tested.

Table 6 contains information regarding the influence of tillage practices on days taken to reach 50 percent flowering and physiological maturity by different rice cultivars during the growth period of the crop. The data shows that both crop growth stages were significantly affected by tillage practices during both years of experimentation.

The number of days the crop took to reach 50 percent flowering and the physiological maturity was lower in the conventional tillage and higher in the NF treatment during the study period of the crop. Higher days taken for 50 percent flowering and physiological maturity in natural farming could be due to the lack of adequate chemical supply to the crop in the treatment, as no chemical fertilizers were used and the inputs used in this practice did not provide the necessary nutrients to the crop. This led to a slow and poor initial plant growth, eventually resulting in more days to reach 50 percent flowering and physiological maturity.

Table 5. Impact of tillage methods on developmental stages of different wheat Cultivars

Treatments	Palampur				Malan			
	Days to 50 %		Physiological		Days to 50 % flowering		Physiological maturity	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
Tillage methods								
Reduced Tillage	127.3	129.7	172.3	176.5	118.3	124.7	165.3	168.7
Zero Tillage	128.4	130.5	173.0	177.7	119.5	125.6	166.8	169.6
Conventional Tillage	127.0	129.9	172.0	175.9	117.9	124.0	165.0	168.1
Natural farming	129.7	131.7	174.5	179.1	120.8	127.2	168.4	170.6
SEm ±	0.5	0.4	0.5	0.6	0.6	0.5	0.5	0.4
CD (P = 0.05)	1.7	1.4	1.6	2.0	2.1	1.9	1.7	1.5
Cultivars								
HPW 349	127.5	130.3	172.3	176.8	119.8	125.7	166.3	169.9
HPW 368	128.5	130.9	173.6	177.9	119.6	126.0	167.0	169.5
HS 562	128.3	130.1	173.0	177.2	118.0	124.6	165.8	168.4
SEm ±	0.4	0.3	0.5	0.5	0.7	0.6	0.5	0.6
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 6. Impact of tillage methods on developmental stages of different rice Cultivars

Treatments	Palampur				Malan			
	Days to 50 % flowering		Physiological maturity		Days to 50 % flowering		Physiological maturity	
	2020	2021	2020	2021	2020	2021	2020	2021
Tillage methods								
Reduced Tillage	81.6	84.0	121.8	124.2	83.3	80.4	123.1	118.9
Zero Tillage	82.2	84.2	122.4	125.1	84.0	80.9	123.8	119.7
Conventional Tillage	81.1	83.2	121.3	123.4	82.8	79.6	122.6	118.6
Natural farming	82.6	84.9	123.4	125.3	84.4	81.3	124.6	120.1
SEm ±	0.3	0.3	0.3	0.2	0.3	0.2	0.4	0.3
CD (P = 0.05)	1.1	1.0	1.2	1.1	0.9	0.7	1.4	1.0
Cultivars								
HPR 1156	81.8	84.3	122.3	124.8	83.6	80.9	123.9	118.8
HPR 2656	81.2	83.3	121.0	123.2	82.5	79.4	122.4	119.2
HPR 2795	82.7	84.7	123.5	125.7	84.8	81.3	124.2	119.9
SEm ±	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
CD (P = 0.05)	0.6	0.7	0.6	0.7	0.5	0.4	0.6	0.6

A two-year study observed that the cultivar HPR 2795 necessitated an extended duration to attain 50% flowering and achieve physiological maturity compared to other cultivars. Conversely, the cultivar HPR 2656 exhibited a significantly shorter duration to reach these developmental milestones in both years. A cultivar's total number of days to get a specific development stage is an inherent varietal characteristic primarily influenced by weather conditions, especially temperature (measured in growing degree days), with minimal impact from tillage methods (22).

Similar outcomes were found at RWRC in Malan for all the above parameters, further validating these findings.

Conclusion

Adopting conventional tillage in a wheat and rice in a rice-wheat cropping system resulted in significantly higher productivity for both crops. At the same time, natural farming failed to give satisfactory results for both crops. Similarly, conventional tillage, as well as reduced tillage, took a lower number of days to achieve flowering as well as physiological maturity. In contrast, natural farming took more days to reach these phenological stages. Among the cultivars tested, HPW 368 of wheat and HPR 2795 of rice yielded better productivity in terms of grain and straw yields. The present study may conclude that conventional tillage resulted in higher productivity and profitability of wheat and rice in the rice-wheat cropping system than other practices evaluated. Also, amongst the different cultivars HPW 368 of wheat and HPR 2795, a new rice variety gave better results under direct seeding.

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Authors' contributions

AS, SM, GS, CS and S performed the experiments. SM, GS, and AG designed the research. AS, CS, S, AS, MK and BB wrote the manuscript. CS, S, AS, MK and BB revised and corrected the manuscript. All authors have contributed to different sections of writing, reviewing, correcting and statistical analysis. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: The authors declare no conflict of interest.

Ethical issues: None

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