



Diverse and healthy cropping systems trial protocol

Location: ICAR-Central Soil Salinity Research Institute, Karnal

Season: 2022-23

December 2022

Research Protocol 4, Work Package 2

BACKGROUND/CONTEXT

On-Farm Research Trials are part of TAFSSA's Work Package 2 (WP2) activities. WP2 emphasizes farm- and landscape-level interdisciplinary research to identify strategies to increase farmers' profits and nutritional yields, conserve resources, and maintain or enhance ecological services, while also mitigating greenhouse gas (GHG) emissions from farms and agricultural landscapes. Going beyond typical agriculture-nutrition programs in South Asia, we explore field- and landscape-scale crop and animal farm diversification options supporting multiple benefits, including

potential nutritional yield, across environmental and socioeconomic gradients of rice and maize-based farming systems. ICAR-CSSRI (Central Soil Salinity Research Institute) Karnal of Haryana in the northwest Indo-Gangetic Plains of India has been selected as basic research and learning site based on key information on food and nutrition security gaps, environmental stresses, air pollution due to residue burning, groundwater exploitation and climate challenges as well as the prevalence of commodities and farming systems that offer the greatest potential to achieve TAFSSA's outcomes.



Above: TAFSSA Trial At Karnal Research Platform

THIS ON-STATION RESEARCH TRIAL WILL CONTRIBUTE TO THE WP2 OUTPUTS:

2.1. Evidence informing the development of extension recommendations and materials tailored and appropriate for men, women, and farmers from marginal groups to build profitable, equitable farming enterprises that support nutrition.

2.2. A decision support framework tailored to South Asia's farming systems supporting governments and communities in managing nutrition-sensitive landscapes.

2.3. Landscape- and watershed-level assessments of groundwater use sustainability.

2.4 At least two public-private partnerships supporting farm services provision business models that overcome innovation bottlenecks to socially inclusive income generation.

2.5 Open-access peer-reviewed papers, reports, and datasets.

As per the Theory of change of WP2 the Research Platform Trial at ICAR-CSSRI (Central Soil Salinity Research Institute), Karnal, Haryana is part of the first impact pathway that focuses on farm diversification and nutrition-sensitive landscapes and will contribute to the outcome "farmers are exposed to innovations and improves management recommendations". This type of action research with national and international research and extension institutes at the national and sub-national levels will facilitate endorsement and use of Outputs 2.1 and 2.3 in development programs implemented by governments, extension agencies, and large livelihood-, environment-, and nutrition-oriented NGOs. Further, these efforts will be aligned with professional capacity development opportunities for young and women professionals within national research systems to learn about innovative tools and methods for answering complex, multi-scale research questions using interdisciplinary methods.

RESEARCH QUESTIONS

Research question 1: At the farm level, can crop diversification, biofortification, and animal components be managed to increase production of nutritious foods and improve women's and men's livelihoods while conserving resources and mitigating Green House Gas (GHG) emissions?

Research question 2: How can foodsheds, watersheds, and airsheds be managed at the landscape level to increase nutritional yields and agrobiodiversity while maintaining or augmenting ecological services?

OBJECTIVES

- Design, test and target the diversified sustainable intensification options to improve system productivity, nutritional yield, resource use and farm profitability.
- Monitor the adaptation behaviour of different crops and cropping systems and their influence on farm animals and nutritional quality.
- Effect of different cropping systems and management practices on soil health, C-budgets, and environmental footprints.

SITE CHARACTERISTICS OF LIVING LABORATORY (CSSRI-KARNAL)

Weather and climate

The climate of the Karnal region is semi-arid tropical and sub-tropical characterized by hot and dry summers and cold winters. The area receives about 748 mm of annual rainfall (mean of 1981 to 2020), about 80 per cent of which occurs during the months of June to September. The mean annual maximum temperature is 30°C while the mean minimum temperature is 17°C and the temperature starts rising from February onwards often exceeding 40-44°C in May or June and relative humidity (RH) remains 60-90% throughout the year. The total annual mean pan evaporation is about 1495 mm.

Soil Characteristics (observed)

The experimental soil is loam in texture with the detail below characteristics:

Historic cropping system history in the region

The rice-wheat cropping system (RWCS) was introduced on a large scale in the state to tide over food insecurity faced by the country. The country, at that time, had to import grains to feed its population. A national-level plan was chalked out for ushering in the Green Revolution and it was widely spread and adopted in the north-western parts covering especially Punjab, Haryana, and Uttar Pradesh of India, and mostly these regions are dependent on groundwater irrigation. With the advent of the Green Revolution, the country's

foodgrain production increased many-fold due to technological intervention. The RWCS is more prominent in Haryana because of favourable agro-climatic conditions, ecological suitability, and availability of natural resources. Further, the irrigation facilities at nominal charges, assured procurement at a minimum support price, the availability of short-statured and high-yielding fertilizer-responsive as well as irrigation-responsive varieties, and good accessibility to machinery for sowing and harvesting operations favour the adoption of RWCS in the region. For these reasons, farmers are reluctant to diversify the existing RWCS. However, this has been at the cost of the state's natural resources, which got depleted and/or deteriorated at a much faster rate than was expected.

Experimental details:

The experiment was started during the monsoon 2022 in the on-going CA research trial, with seven treatments referred to as scenarios (S) at the research farm of Indian

Council of Agricultural Research (ICAR) - Central Soil Salinity Research Institute (CSSRI) (29°70' N, 76°95' E), Karnal, India. It falls under *Typic Natrustalf* category. The term scenario can be described as it is a portfolio of practices where more than two agronomic interventions are included in each treatment to see the combined effect of different management agronomic practices.

Irrigation water management:

A polyvinyl chloride (PVC) pipeline was installed in a 60 cm deep trench with an outlet for each plot separately which is connected to a deep electricity-pumped tube well. On-line water meter (Woltman® helical turbine) was fitted for irrigation water measurement. Water meter readings were recorded for each irrigation to calculate the amount of irrigation water applied per plot.

SUSTAINABLE INTENSIFICATION OPTIONS FOR TRANSFORMING AGRIFOOD SYSTEMS IN WESTERN IGP TO ADDRESS FOOD & NUTRITIONAL SECURITY

Particulars	Value
Sand (%)	34
Silt (%)	46.1
Clay (%)	19.9
Soil aggregation stability	46.2
pH (1:2 soil:water)	8.12
EC	0.26
Organic Carbon	0.48
Available N (kg ha ⁻¹)	146.34
Available P (kg ha ⁻¹)	19.02
Available K (kg ha ⁻¹)	220.2

Scenarios	Drivers of change	Crop Rotations	Tillage	Crop Establishment Method	Residue Management
1	Business as usual (farmer's practice)	rice-wheat - fallow	PTR-CT	rice: transplanting; wheat: broadcast -on flats	full rice and partial wheat residue burning
2	Improved production, income, and nutrition through intensification	rice-potato-spring pearl millet	CT DSR-CT-CT	rice: drill seeding on flats; potato: manually; pearl millet: drill seeding -on fresh beds	all crop residue removal
3	Sustainable intensification to address the issues of labor, water, energy, malnutrition, soil health degradation	rice-wheat-mung bean	ZT DSR-ZT-ZT	rice: drill seeding; wheat: drill seeding; mung bean: drill/relay -on flats	full (100%) rice; anchored wheat (25-30%) and full mung bean residue retention
4	Sustainable intensification to address the nutrition along with labor, water, and soil health	maize-mustard-mung bean	ZT-ZT-ZT	maize: drill seeding; mustard: drill seeding; mung bean: drill/relay -on permanent beds (pbs)	anchored maize (60-70%) and mustard (30-40%) and full mung bean residue retention
5	Sustainable intensification to deal with human and animal demand for nutritious food and fodder	baby corn-carrot-cowpea (dual purpose)	ZT-CT-CT	baby corn: drill seeding; carrot: manually; cowpea: drill seeding -on fresh beds	anchored cowpea (15-20%) residue retention
6	Sustainable intensification to address labor, water, nutrition, and animal green fodder	soybean-wheat-sorghum (fodder)	ZT-ZT-ZT	soybean: drill seeding; wheat: drill seeding; sorghum: drill seeding -on pbs	anchored soybean (~20%) and wheat (~30%) and sorghum (~15%) residue retention
7	Sustainable intensification to address labor, water, and nutrition	pearl millet-pea-sunflower	ZT-ZT-ZT	pearl millet: drill seeding; pea: drill seeding; sunflower: drill seeding -on pbs	pearl millet (~15%); full pea and sunflower residue retention

Design: Factorial Randomized block design (RBD)

Cropping systems and management options

(Scenarios): 7

Replications: 3

Plot size: 55 m X 10m = 550 m²

Start of year and season: Monsoon 2022



KEY CHALLENGES ADDRESSED

- Focused on hot-spots of poverty, malnutrition, and ecological degradation in the TAFSSA's learning locations, activities in the rice-based systems of the EGP; the mixed farming and rice-fallow systems of eastern India.
- Research will yield insights supporting sustainable and nutrition-sensitive landscapes, while also developing business models and pathways for policies supporting income generation.

RICE

Season	:	Kharif (Monsoon June to October)
Rotations	:	Rice-Wheat-Fallow
Variety	:	Arize (AZ6585ST)
Variety characteristics		
Crop duration (Days)	:	120-125 days seed to seed
Average grain yield (t/ha)	:	7.5 t/ha
Special characteristics (if any)		
<ul style="list-style-type: none"> • High yielding hybrid rice variety of Bayer crop science in early duration segment compared to other varieties grown in similar ecology. • Stronger biotic stress tolerance and protection in the fight against devastating pests and disease, especially BLB. • More tolerance to fight against abiotic stress which more resilient to adverse climatic conditions. 		
Seed Rate kg/ha		
Transplanted rice	:	15
Direct seeded rice	:	20
Sowing time (Transplanting)	:	Last week of June to 1 st week of July depending access of field and onset of monsoon
Time of nursery	:	25 May to 15 June
Age of transplanting	:	21-25 Days (Seedlings more than 30 days old when transplanted recover more slowly than younger seedlings, especially if they suffer stem and root injury. Seedlings less than 20 days old are too short to be pulled from the soil).

Land preparation

Conventional transplanted rice (CT TPR)

After harvesting of the previous wheat crop in the rice-wheat fallow system, the plot will be tilled with cross harrow and one tiller then left for a few days. The plot will be ponded through irrigation water. If sufficient rainfall event will not occur, then plot will be churn through the wet tillage (puddling) using either a puddling harrow or rotary tillage. Allow the soil for one days for settling the soil particles before transplanting. Transplant the two seedlings per hill and by maintaining 30-32 hills per square meter. The seedlings should be transplanted upright and about 2-3 cm deep.

Conventional directed seeded rice (CT DSR)

After harvesting of the previous pearl millet crop in the rice-potato-pear millet system, the plot will be tilled with a cross harrow and one tiller then pressed and leveled using a wooden planker. Rice seeds will be sown by using the inclined plate seed metering system zero till multi-crop planter. The seed will be placed at the depth of about 2-cm soil depth in a row spacing of 22.5 cm. Immediately after seeding, light irrigation will be applied to ensure proper germination.

Zero-till directed seeded rice (ZT DSR)

At the final mung bean pod harvest, the whole mung bean crop biomass will be kept in the plot a under rice-wheat-mung bean cropping system and knockdown by spraying the non-selective herbicide paraquat @ 2 litre per ha (500 gm a.i. per ha). If sufficient soil moisture is not available in the soil then apply light irrigation and necessary then also apply Glyphosate (2.5 litre per ha) to knock down the existing perennial weeds. Rice seeds will be sown by using the inclined plate seed metering system zero till multi-crop planter/happy seeder. The seed will be placed at the depth of about 2-cm soil depth in a row spacing of 22.5 cm. Immediately after seeding, light irrigation will be applied to ensure proper germination.

Weed management	
Transplanted rice	<p>Pre-emergence- After transplanting of rice seedlings, within 2 days of transplanting applied butachlor 3ltr/ ha in stagnant water for weed control</p> <p>Post-emergence- Spray 250 ml/ha as a Nominee Gold (bispyribac) diluting in 375 litres of water, at 20-25 days of transplanting, depending on the weed flora complex, this can be combined with Pyrazosulfuron and this will be assessed before the post-emergence herbicide application.</p>
CTDSR	<p>Pre-emergence- Depending on the field access within two-three days of seeding, a pre-emergence herbicide as Pendimethalin (40%) @ 2.5 litre per ha will be sprayed diluting in the 300-350 litre of water.</p>
ZT DSR	<p>Post-emergence- Within 15-25 days of sowing applied bispyribac sodium 250ml and Pyrazosulfuron Ethyl 10% WP 200 g/ha.</p> <p>Pre-plant- If necessary, apply Glyphosate (2.5 litre per ha) to knock down the existing perennial weeds.</p> <p>Pre-emergence- Depending on the field access within two-three days of seeding, a pre-emergence herbicide as Pendimethalin (40%) @ 2.5 litre per ha will be sprayed diluting in the 300-350 litre of water.</p> <p>Post-emergence- After 15-25 days of sowing applied bispyribac sodium 250ml and Pyrazosulfuron Ethyl 10% WP 200 gram/ha.</p>
Time of nursery	25 May to 15 June.
Age of transplanting	21-25 Days (Seedlings more than 30 days old when transplanted recover more slowly than younger seedlings, especially if they suffer stem and root injury. Seedlings less than 20 days old are too short to be pulled from the soil).

Nutrient management (TPR)

Nutrient requirements are assessed through the nearby farmers under business-as-usual conventional practice and this will be updated after every 2 years. The below nutrients will be followed in conventional rice crops.

Nitrogen (kg/ha)	195
Phosphorus (kg/ha)	57
Potassium (kg/ha)	5
Any other Nutrient	Depending on the Zn, requirement ZnSO ₄ will be applied. The 1/3rd dose of N and full dose of P ₂ O ₅ and K ₂ O will be applied at the time of sowing and remaining 2/3rd dose of N will be applied in two equal splits at 15-20 DAT, and 40-45 DAT

Nutrient management (DSR)

The recommended dose of nutrients applied in DSR plots

Nitrogen (kg/ha)	150
Phosphorus (kg/ha)	60
Potassium (kg/ha)	60
ZnSO₄ (21%)	25
Any other Nutrient	In both CT and ZT DSR the 1/3rd dose of N and full dose of P ₂ O ₅ and K ₂ O will be applied at the time of sowing and remaining 2/3rd dose of N will be applied in two equal splits at 25-30 DAS, and 45-55 DAS. In DSR, also apply 2 or 3 sprays of one per cent ferrous sulphate solution at weekly intervals for appearance of iron deficiency (1 kg of ferrous sulphate in 100 litres of water per acre) and this will be assessed depending on rainfall pattern and climate.

Irrigation management

PTR	Keep the water standing continuously in the crop for two weeks only after transplanting so that the seedlings get properly established. After that, apply irrigation at hairline cracks appearance
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DSR	Apply first irrigation immediately after sowing and second irrigation at 4-5 days after sowing. Subsequent irrigations should be applied at 5-7 days intervals depending on soil type or irrigation interval adjusted according to rainfall. Stop irrigation 10 days before harvesting
Irrigation method	Flood
No. of irrigations	Each and every event of irrigation will be recorded and measured for individual plots using the digital flow meter.
Plant height at harvest (cm)	5 plants at 4 locations in each plot
No. of tillers at harvest (sq m)	Count the effective tillers in 2x 2 square meter quadrat
No. of grains per panicle	Count the grains of 5 plants at 2 locations each plot
1000 grain weight (g)	Count the 1000 grains with seed counter and weight with precise balance and record in grams
Biological yield (t/ha)	Carefully mark the 5m by 5m plot avoiding the borders and harvest the rice within the marked area for both biological and grain yield estimation. Sub-sample for moisture estimation.
Grain and straw yield (t/ha)	After threshing the grain, weigh the grain weight and deduct the grain yield from the total biological yield after moisture adjustment. After threshed the grain, the whole rice straw will be returned to the original (5m by 5m) area in each rice plot.
Protein content analysis	Adopted standard method (HAU nutrition scientist will assist and facilitate)
Fat content	Adopted standard method for fat estimation (HAU nutrition scientist will assist and facilitate)
Iron content	Perkin & Elmer Method
Zinc content	Perkin & Elmer Method

MAIZE (GRAIN PURPOSE)

Season	Karif (Monsoon June-October)
Rotations	Maize-Mustard-Mungbean (ZT-ZT-ZT) (All three crops established on permanent beds)
Grain maize	
Variety (high yielding hybrid)	CP858 Normal
Variety characteristics	
Crop duration (Days)	Medium maturity (100-105 days)
Average Grain Yield (t/ha)	8-10 t/ha
Special characteristics (if any)	
<ul style="list-style-type: none">• Stay green till maturity therefore can use for dual purpose (seed and green fodder)• High yielding variety in kharif season in this climatic zone compared to other hybrid varieties	
Variety (Biofortified)	IQMH-203
Crop duration (Days)	Early maturity (80-90 days)
Average grain yield (t/ha)	Grain yield 6.5 to 7.5 t/ha
Special characteristics (if any)	
<ul style="list-style-type: none">• Rich in lysine (3.48 % in protein) and tryptophan (0.77 % in protein) biofortified variety compared to other popular hybrids	
Seed rate kg/ha	20 (75000 to 83000 plants/ha)
Sowing Time	20 June to 15 July depending on the access of field
Crop establishment methods	Permanent beds (no-till system) under maize-mustard-mung bean diversified system
Sowing method	After the chemical (herbicide) knockdown of the previous crop mung bean, carry forward wheat crop residue and whole mung bean residue on the surface soil as mulch. Simultaneously reshape and place the maize seed and fertilizer on the center of the bed using the disc-type multi-crop inclined plate bed planter. Space between the center of beds is 67.5 cm and approximate maintaining the 20cm spacing between two plants
Nutrient Management	
Nitrogen (kg/ha)	150
Phosphorus (kg/ha)	60
Potassium (kg/ha)	60
Zink Sulphate (21%)	25
Application	Apply entire quantity of P and K at the time of sowing and 1/3 rd of N. Top dress the remaining nitrogen in two equal splits at the V10-12 stage and at the pre-tasseling stage.

Irrigation management

Irrigation Method	The supplemental furrow irrigation will be applied as per the rainfall pattern and when a crop needs water in long dry spell between rainfall events. Each irrigation amount of water will be monitored and recorded through the flow water meter.
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Weed management:

Pre-plant herbicide application will be assessed after the harvest of mung bean crop and if necessary, then apply Glyphosate @ 2.5 litre per ha diluting in 400 litre of water to knock down the existing perennial weeds.

As a post-emergence, Tembotrione (Laudis) selective herbicide @120 g per ha will be applied at two-three leaf stage of weeds (15-20 DAS) following the all-herbicide application guidelines

Observations to be recorded for Grain Maize

Plant height at harvest (cm)	5 plants, 4 locations in each plot
No. of plant at harvest (sq m)	Count the plants from 2 beds x 4-meter row length
No. of cob/plant	Count the cobs from 2 beds x 4 meter row length
Cob length	Measure the 5-cobs from each sample, two samples from each plot.
No. of grain per cob	Count the grains from 5 cobs from each sample, two samples from each plot
100 grain weight (g)	Count the 100 grains using the seed counter and weigh 100 grain weight (g)
Biological yield (t/ha)	Mark the area of 2 beds x 4-meter length, then harvest the whole crop carefully and weigh the total biomass weight. Sub-sample will be taken for moisture determination
Grain Yield (t/ha) and stover yield	Separate the cobs and plants from the harvested area of 2 bed x 4-meter length. Thresh the cobs carefully and weigh the total grain weight and cobs husk weight separately (After adjustment of moisture, the grain weight is deducted from biological yield to get the total stover weight including cob husk and sheath), after cob harvest, the remaining 70% plant biomass will be returned to the original harvested area.
Protein content analysis	Adopted standard method (HAU nutrition scientist will assist and facilitate)
Fat content	Adopted standard method for fat estimation (HAU nutrition scientist will assist and facilitate)
Iron content	Perkin & Elmer Method
Zinc content	Perkin & Elmer Method

MAIZE (BABY CORN)

Season	Karif (Monsoon June-October)
Rotations	Baby corn-Carrot-Cowpea (Dual purpose) (ZT-CT-CT) (Baby corn on ZT-beds and Carrot and Cowpea on fresh beds)
Variety (Baby Corn)	G-5414
Crop duration (Days)	Medium maturity variety (50-55 days)
Average grain yield (t/ha)	With husk 7.5 – 10 t/ha, without husk 5-6.5 t/ha
Special characteristics (if any)	
<ul style="list-style-type: none">• Beautiful ears with fine ovary arrangement• Uniform sized creamy ears• Good and long shelf-life• Suitable for both fresh and processing markets	
Seed rate kg/ha	25
Sowing time	20 June to 15 July depending on the access of field and climate
Sowing method	After harvest of cowpea as fodder and grain but keeping about 20% crop residue as stubbles. Simultaneously reshape and place the maize seed and fertilizer on the center of the bed using the disc-type multi-crop inclined plate bed planter. Space between center of beds is 67.5 cm and approximate maintaining the 20cm spacing between two plants.
Nutrient management	
Nitrogen (kg/ha)	87
Phosphorus (kg/ha)	30
Potassium (kg/ha)	20
Application	Apply entire quantity of P and K at the time of sowing. Top dress remaining nitrogen after first harvest of the baby corn.
Irrigation management	
Irrigation method	Need based supplementary furrow irrigation will be applied and each irrigation event will be measured through the water flow meter with date and time.

Weed management:	<p>Pre-plant herbicide application will be assessed after the harvest of mung bean crop and if necessary, then apply Glyphosate @ 2.5 litre per ha diluting in 400 litre of water to knock down the existing perennial weeds.</p> <p>As a post-emergence, Tembotrione (Laudis) selective herbicide @120 g per ha will be applied at two-three leaf stage of weeds (15-20 DAS) following the all-herbicide application guidelines</p>
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Observations to be recorded for Baby Corn

Plant height at Harvest (cm)	5 plants, 4 locations each plot
No. of plant at harvest (sq m)	Count the plants from 2 bed x 4 meter length
No. of cob/plant	2 bed x 4 meter length (the number of baby corn cobs will be counted in each harvest)
Cob weight	Weight the total harvested cob weight from harvested areas in each harvest (2 bed x 4 meter length).
Yield (t/ha)	2 bed x 4 meter length (each harvest will be summed and reported as total fresh baby corn yield)
Stover yield	2 bed x 4 meter length (At the last harvest, the total green fodder will be harvested and reported as green fodder but also collect the sub-sample for moisture determination to estimate the dry crop biomass and yield.
Protein content analysis	Adopted standard method (HAU nutrition scientist will assist and facilitate)
Fat content	Adopted standard method for fat estimation (HAU nutrition scientist will assist and facilitate)
Iron content	Perkin & Elmer Method
Zinc content	Perkin & Elmer Method

SOYBEAN

Season	Kharif
Rotations	Soybean – Wheat – Sorghum (Fodder) (ZT-ZT-ZT)
Variety	SL 958
Crop duration (Days)	135 to 142 days
Average grain yield (t/ha)	1.8 t/ha

- **High in protein (41.7%) and oil (20.2%).**
- **It is highly resistant to yellow mosaic virus and soybean mosaic virus.**

Seed rate kg/ha	62.5 - 75
Sowing Time	First fortnight of June.

Agronomic practices

Method of sowing:

After harvesting of sorghum fodder crop but keeping about 20% crop residue as stubbles simultaneously re shape and place the soybean seed and fertilizer two rows on the top of the bed using the disc-type multi-crop inclined plate bed planter. Space between two rows is 30 cm and approximate maintaining the 4-5 cm spacing between plant to plant.

Nutrient management

Nitrogen (kg/ha)	25
Phosphorus (kg/ha)	80
Application	Apply entire quantity of N and P at the time of sowing.

Irrigation management

Irrigation method	The supplemental furrow irrigation will be applied as per the rainfall pattern and when a crop needs water in long dry spell between rainfall events. Each irrigation amount of water will be monitored and recorded through the flow water meter.
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Weed management	Pre-plant herbicide application will be assessed after the harvest of sorghum fodder crop and if necessary, then apply Glyphosate @ 2.5 litre per ha diluting in 400 litre of water to knock down the existing perennial weeds. As a post-emergence, Imazethapyr (Pursuit) selective herbicide @750 ml/ha will be applied at two-three leaf stage of weeds (20-25 DAS) following the all-herbicide application guidelines
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Observations to be recorded	
No. of plant at harvest (sq m)	Count the plants from 2 beds 4 meter in length
No. of pods plant⁻¹	Count the pods from 5 plants, 4 locations in each plot
No. of seeds pod⁻¹	Count the seed from 5 pods, 4 locations in each plot
100 grain weight (g)	Count the 100 grains and weigh 100 grain weight (g)
Grain yield & stover yield (t/ha)	Mark the area of 2 beds 4 meter in length, harvest the total biomass carefully and record the weight as a biological yield. Thresh the grain from the biomass and weigh the total grain weight. Sub-sample of biomass and grain will be collected for moisture determination
Protein content analysis	Adopted standard method (HAU nutrition scientist will assist and facilitate)
Fat content	Adopted standard method for fat estimation (HAU nutrition scientist will assist and facilitate)
Iron content	Perkin & Elmer Method
Zinc content	Perkin & Elmer Method

WHEAT

Season	:	Rabi
Rotations	:	Rice-Wheat-Fallow
Variety	:	DBW-222 Normal
Variety characteristics		
Crop duration (Days)	:	139-150 days seed to seed
Average grain yield (t/ha)	:	6.1 t/ha
Special characteristics (if any)		
<ul style="list-style-type: none"> Resistant to brown rust, moderately resistant to yellow rust. Good bread making quality 		
Variety	:	WB 02 Biofortified
Crop duration (Days)	:	129-157 days
Average grain yield (t/ha)	:	5.1 t/ha
Special characteristics (if any)		
<ul style="list-style-type: none"> Resistant to brown rust, moderately resistant to yellow rust. Zinc (42.0 ppm) and iron (40.0 ppm) biofortified variety. 		
Seed rate kg/ha	:	112.5 – 125
Sowing time	:	4 th Week of October to 2 st Week of November
Agronomic practices		

<p>Land preparation</p> <p>Conventional tillage wheat (CTW)</p> <p>Zero-till wheat (ZTW)</p> <p>Permanent bed wheat (PBW)</p>	<p>:</p> <p>:</p> <p>:</p>	<p>After harvesting of the previous rice crop in the rice-wheat fallow system, the rice residue will be removed from the plot and the plot will be irrigated if sufficient moisture is not available. At the time of appropriate moisture condition the plot will be tilled with cross one harrow, one tiller and one rotary tiller after that wheat seed will be broadcasted and mixed in soil using rotary tiller.</p> <p>At final rice harvest, the whole rice crop biomass will be kept in the plot under rice-wheat-mung bean cropping system. If sufficient soil moisture is not available in the soil then apply light irrigation and necessary then also apply Glyphosate (2.5 litre per ha) to knock down the existing perennial weeds. Wheat seeds will be sown by using the fluted roller seed metering system zero happy seeder. The seed will be placed at the depth of about 5-7 cm soil depth in a row spacing of 22.5 cm.</p> <p>After harvesting of soybean crop but keeping about 20% crop residue as stubbles/litterfall and place the wheat seed and fertilizer two rows on the top of the bed using the disc-type multi-crop inclined plate bed planter. Maintaining space between two rows is 30 cm.</p>
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Weed management

<p>CTW</p> <p>ZTW & PBW</p>	<p>:</p> <p>:</p>	<p>Post-emergence- Within 25-35 days of sowing applied Pinoxaden (Axial) @1 ltr/ha and Metsulfuron methyl (Algrip) 20% WP @20 g/ha.</p> <p>Pre-plant- If necessary apply Glyphosate (2.5 litre per ha) to knock down the existing perennial weeds.</p> <p>Post-emergence- Within 25-35 days of sowing applied Pinoxaden (Axial) @1 ltr/ha and Metsulfuron methyl (Algrip) 20% WP @20 g/ha.</p>
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Nutrient Management (CTW)

Nutrient requirement is assessed through the nearby farmers under business-as-usual conventional practice, and this will be updated after every 2 years. The below nutrients are applied in conventional rice crops.

Nitrogen (kg/ha)	:	166
Phosphorus (kg/ha)	:	57
Potassium (kg/ha)	:	5
Zink Sulphate (21%)	:	25
Application method	:	Entire dose of P and K will be applied at the time of sowing and N will be applied in two equal splits at 22-25 DAS, and 42-45 DAS

Nutrient management (ZTW)
The recommended dose of nutrients applied in ZTW and PBW plots

Nitrogen (kg/ha)	:	150
Phosphorus (kg/ha)	:	60
Potassium (kg/ha)	:	60
ZnSO₄ (21%)	:	25
Application method	:	Full dose of P ₂ O ₅ and K ₂ O will be applied at the time of sowing and N will be applied in two equal splits at 22-25 DAS, and 42-45 DAS

Irrigation management

CTW, ZTW & PBW	:	Apply first irrigation at CRI stage 22-25 DAS and subsequent irrigations should be applied at 20-25 days intervals depending on soil type and moisture condition.
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Irrigation management

CTW & ZTW	:	Flood
PBW	:	Furrow
No. of irrigation	:	4-5 depending on soil type and moisture condition. Each and every event of irrigation will be recorded and measured for individual plots using the digital flow meter.

Observations to be recorded

No. of tillers at Harvest (sq m)	:	CTW: 0.5 x 0.5 square meter quadrat ZTW & PBW: 2 rows 1 meter row length
No. of Grains per panicle	:	5 plants, 2 locations in each plot
1000 grain weight (g)	:	Count the 1000 seed with seed counter and weight with precise balance and record in grams

Biological yield (t/ha) : **CTW & ZTW: Carefully marked the 5m by 5m plot avoiding the borders and harvest the wheat within the marked area for both biological and grain yield estimation. Sub-sample for moisture estimation.**
PBW: Carefully marked the 2 bed 4 meter row length area, avoiding the border lines and harvest the wheat within the marked area for both biological and grain yield estimation. Sub-sample for moisture estimation.

Grain and straw yield (t/ha) : CTW & ZTW: After threshing formed the marked area (5m X 5m) grain, weigh the grain weight, and deduct the grain yield from the total biological yield after moisture adjustment.
 PBW: After threshing formed the marked area (2 bed 4 meter row length) grain, weigh the grain weight and deduct the grain yield from the total biological yield after moisture adjustment.

1000 grain weight (g) : Count the 1000 seed with seed counter and weight with precise balance and record in grams

Protein content analysis : Adopted standard method (HAU nutrition scientist will assist and facilitate)

Fat content : Adopted standard method for fat estimation (HAU nutrition scientist will assist and facilitate)

Iron content : Perkin & Elmer Method

Zinc content : Perkin & Elmer Method

PEA

Season : **Rabi**

Rotations : Pearl millet – Pea – Sunflower

Variety : HFP 1428

Variety characteristics

Crop duration (Days) : 123 days

Average grain Yield (t/ha) : 2.6-2.8 t/ha

Special characteristics (if any)

- **High yielding dwarf variety**
- **Resistant to Powdery mildew, Ascochyta blight and Root rot and moderately resistant to Rust.**
- **Resistant to lodging.**

Seed rate kg/ha	75
Sowing time	: First fortnight of November
Agronomic practices	
Method of sowing:	
After harvesting pearl millet crop but keeping about 15% crop residue as stubbles and place the pea seed and fertilizer two rows on the top of the bed using the disc-type multi-crop inclined plate bed planter. Maintaining space between two rows is 30 cm and plant to plant 20 cm.	
Weed management	: Pre-plant- If necessary apply Glyphosate (2.5 litre per ha) to knock down the existing perennial weeds. Post-emergence- Within 25-35 days of sowing applied Quizalofop ethyl (Targa super) 10% EC @ 625 ml/ha.
Nutrient management	
Recommended dose	
Nitrogen (kg/ha)	: 20
Phosphorus (kg/ha)	: 40
Application	: Entire dose of N and P applied at the time of sowing
Irrigation management	
Irrigation method	: Furrow Irrigation
No. of irrigations	: 3-4 irrigation and each and every event of irrigation will be recorded and measured for individual plots using the digital flow meter. Each and every event of irrigation will be recorded and measured for individual plots using the digital flow meter.
Observations to be recorded	
No. of plant at Harvest (sq m)	: Count the plants from 2 bed 4 meter row length
100 grain weight (g)	: Count the 100 grains and weigh as a 100 grain weight (g)
Grain yield (t/ha)	: Mark the area of 2 bed 4 meter in row length, harvest the pods and weigh the total fresh weight. (If green pea then each harvest will be recorded and summed the total number of harvest pod weight, in case of field pea the one harvest will be recorded)

Biological yield (t/ha)	:	Total biomass will be harvested from 2 bed 4 meter row length
Protein content analysis	:	Adopted standard method (HAU nutrition scientist will assist and facilitate)
Fat content	:	Adopted standard method for fat estimation (HAU nutrition scientist will assist and facilitate)
Iron content	:	Perkin & Elmer Method
Zinc content	:	Perkin & Elmer Method
MUSTARD		
Season	:	Rabi
Rotations	:	Maize – Mustard - Moong
Variety	:	CS 58 (Normal)
Variety characteristics		
Crop Duration (Days)	:	125-130 days
Average grain yield (t/ha)	:	3.0 t/ha
Special characteristics (if any)		
<ul style="list-style-type: none"> • Salt, and alkaline tolerant cultivar • It yields around 39% oil content even under salt stress conditions. • Highly resistance to Alternaria blight under natural conditions 		
Variety	:	Pusa Double Zero 31 Biofortified
Crop duration (Days)	:	142 days
Average grain yield (t/ha)	:	2.5 t/ha
Variety characteristics		
<ul style="list-style-type: none"> • Canola quality Indian mustard variety • Low in erucic acid (0.76 % in oil) and glucosinolates (29.41 ppm in seed meal) in comparison to >40.0 % erucic acid and >120.0 ppm glucosinolates in popular varieties. • High oil content (41.0 %) 		
Seed rate Kg/ha	:	3.75
Sowing time	:	1 st week of October
Agronomic practices		

Method of sowing:

After harvesting of maize crop but keeping about 70% crop residue as stubbles under maize-mustard-mung bean rotation and place the mustard seed and fertilizer two rows on the top of the bed using the disc-type multi-crop inclined plate bed planter. Seed mix with DAP and drop through fluted roller to ensure uniform distribution in the field. Space between two rows is 30 cm and approximate maintaining the 10-15 cm spacing between plant to plant.

Weed management	:	Pre-plant- If necessary, apply Glyphosate (2.5 litre per ha) to knock down the existing perennial weeds.
	:	Post emergence weed control- One spot hand weeding will be done based on the weed density to remove escaped weeds.

Nutrient management

Nitrogen (kg/ha)	:	80
Phosphorus (kg/ha)	:	30
Potassium (kg/ha)	:	20
Application	:	Apply full dose of P & K at the time of sowing and N is apply in two splits, first split at first irrigation and second split at second irrigation.

Irrigation management

Irrigation method	:	Need based supplementary pre sowing furrow irrigation will be applied if sufficient moisture is not available at the time of sowing. The first irrigation was applied at 3 to 4 weeks after sowing, further two irrigations were applied at siliqua formation and flowering stage and each irrigation event will be measured through the water flow meter with date and time.
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Observations to be recorded

Plant height at harvest (cm)	:	5 plants, 4 locations each plot
No. of plants at harvest (sq m)	:	Count the number of plants from 2 bed 4-meter length
Biological yield (t/ha)	:	Mark the area of 2 bed 4-meter length, harvest carefully and weigh the total biomass. Sub-sample for moisture determination.
1000 grain weight (g)	:	Count the 1000 grains using the seed counter and weigh the 1000 grain weight (g)
Grain yield and straw yield (t/ha)	:	Thresh the biomass from 2 bed 4-meter length, weight the grains, deduct the grain weight from the biomass and calculate the stover weight and record. Sub-sample of grains for moisture content.

Protein content analysis	:	Adopted standard method (HAU nutrition scientist will assist and facilitate)
Fat content	:	Adopted standard method for fat estimation (HAU nutrition scientist will assist and facilitate)
Iron content	:	Perkin & Elmer Method
Zinc content	:	Perkin & Elmer Method

POTATO

Season	:	Rabi
Rotations	:	Rice – Potato - Pearl millet (CTDSR-CT-CT)
Variety	:	Kufri Pukhraj

Variety characteristics

:

Crop duration (Days) Early maturity variety (70-90 days)

Average grain yield (t/ha)	:	40 t/ha
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Special characteristics (if any)

- **Resistant to early blight, moderately resistant to late blight and immune to wart disease.**
- **Suitable for low input eco-system.**
- **Suitable for table purpose**

Variety	:	Kufri Neelkanth Biofortified
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Crop Duration (Days)	:	Medium maturity (90-100 days)
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:

Average grain yield (t/ha) High yielding variety (36-38 t/ha)

Special characteristics (if any)

- **Rich in anthocyanin (1.0 ppm) in comparison to negligible content in popular varieties**
- **High in antioxidants**

Seed rate t/ha 1.75 – 2.5 medium sizes

Sowing time	:	Last week of October
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Agronomic practices

Land preparation:

After harvesting of the previous rice crop in the Rice – Potato - Pearl millet system, the rice residue will be removed from the plot and the plot will be irrigated if sufficient moisture is not available. At the time of appropriate moisture condition the plot will be tilled with cross two harrow, two tiller and two rotary tiller after that fresh bed prepared using curved/narrow-blade spade raised bed planter.

Method of sowing:

After preparation of field, the potato tubers placed on top of the ridges manually and covering it with soil maintaining 10-15 cm seed depth. A spacing 60 cm between rows and 20 cm between plan to plant is maintained.

Nutrient management

Nitrogen (kg/ha) : 150

Phosphorus (kg/ha) : 80

Potassium (kg/ha) : 100

Application :

Entire dose of P, K at the time of sowing and Half of the N dose will be applied at the time of sowing and rest half dose of N applied at 25-30 DAS.

Irrigation management

Irrigation method :

The first light irrigation was applied at 3 to 4 DAS as it ensures better germination. Subsequent irrigations should be applied at 10-12 days intervals depending on soil type or irrigation interval adjusted according to soil moisture condition.

Each and every event of irrigation will be recorded and measured for individual plots using the digital flow meter.

Weed management :

Pre-emergence- Depending on the field access within two-three days of seeding, a pre-emergence herbicide as Pendimethalin (40%) @ 2.5 litre per ha will be sprayed diluting in the 300-350 litre of water. Post-emergence- Within 20-25 days of sowing applied metribuzin 70% WP (sencor) 500 g/ha.

Observations to be recorded

No. of plant at Harvest (sq m)	:	Count the plants from 2 bed x 4 meter length
No. of tuber/plant	:	Count the tubers from representative 5 plants, 4 locations in each plot
Tuber yield (t/ha)	:	Mark the area of 2 beds x 4 meter in length, digging out the tubers, and weigh the weight of the total tubers.
Protein content analysis	:	Adopted standard method (HAU nutrition scientist will assist and facilitate)
Fat content	:	Adopted standard method for fat estimation (HAU nutrition scientist will assist and facilitate)
Iron content	:	Perkin & Elmer Method
Zinc content	:	Perkin & Elmer Method

CARROT

Season	:	Rabi
Rotations	:	Baby corn – Carrot – Cowpea (Dual purpose)
Variety	:	Nantindo F1
Variety characteristics		
Crop duration (Days)	:	120-130 days
Average grain yield (t/ha)	:	90 t/ha
Special characteristics (if any)		
<ul style="list-style-type: none">• Late maturity hybrid variety• Excellent force growth, large roots with a diameter of 3.5 - 5.5 cm and length 20 cm.• Potentially very high-yielding hybrid for this climatic zone.• High uniformity with collection and easy harvest.• Tolerant to Alternaria, ingrowth of flower shoots in the first year of vegetation and well tolerated heat.		
Seed rate kg/ha	:	1.87
Sowing time	:	First week of October
Agonomic practices		

Land preparation:

After harvesting of the previous baby corn crop in the Baby corn – Carrot – Cowpea (Dual purpose) system, the baby corn residue will be removed from the plot and the plot will be irrigated if sufficient moisture is not available. At the time of appropriate moisture condition the plot will be tilled with cross two harrow, two tiller and two rotary tiller after that fresh bed prepared using curved/narrow-blade spade raised bed planter.

Method of sowing:

After preparation of field, the sowing of carrot will be done using tractor drawn inclined plates carrot planter. The sowing of carrot seeds will be done on seed beds. The machine will be made two beds and seeding four rows on a bed with width of 67.5 cm maintaining row spacing of 10 cm and plant to plant spacing of 8 cm.

Nutrient management

Nitrogen (kg/ha) : 80

Phosphorus (kg/ha) : 115

Potassium (kg/ha) : 75

Zinc Sulphate 21% : 12 kg/ha

Application : Entire dose of P, K and ZnSO₄ at the time of sowing and N is apply in two splits first dose applied at 35 DAS and second dose of split at 60-65 DAS.

Irrigation management

Irrigation method : The first light irrigation was applied immediately after sowing to ensure better germination. Subsequent irrigations should be applied at 12-15 days intervals depending on soil type or irrigation interval adjusted according to soil moisture condition.
Each and every event of irrigation will be recorded and measured for individual plots using the digital flow meter.

Weed management

:
Pre-emergence- Depending on the field access within two-three days of seeding, a pre-emergence herbicide as Pendimethalin (40%) @ 2.5 liter per ha will be sprayed diluting in the 300-350 litre of water.
Post-emergence- Within 20-25 days of sowing applied metribuzin 70% WP (sencor) 250 g/ha.

Observations to be recorded

Plant Population : No of plants per meter row length of 4 rows

Tap root length(cm) : Measure the length of 5 plants at 4 locations in each plot

Biological yield (t/ha)	:	Mark the area of 2 bed 4-meter length, harvest the green above biomass and then digging out the carrot root, wash the carrot and weigh the total weight. Sum both green biomass and root. Take the sub-sample of green biomass for dry biomass.
Taproot yield (t/ha)	:	Weigh the total harvest carrot root after proper washing from 2 bed 4-meter length.
Haulm yield(t/ha)	:	Weigh the total above biomass from 2 bed 4 meter length
Protein content analysis	:	Adopted standard method (HAU nutrition scientist will assist and facilitate)
Fat content	:	Adopted standard method for fat estimation (HAU nutrition scientist will assist and facilitate)
Iron content	:	Perkin & Elmer Method
Zinc content	:	Perkin & Elmer Method

MOONG (SUMMER MOONG)

Season	:	Summer
Rotations	:	Rice – Wheat – Moong Maize – Mustard – Moong
Variety	:	MH 421 (Short Duration Moong)
Variety characteristics		
Crop duration (Days)	:	60-62 days
Average grain yield (t/ha)	:	1.0-1.2 t/ha in summer
Special characteristics (if any)		
<ul style="list-style-type: none"> • Non-shattering, Resistant to Yellow Mosaic Virus • The flavour of the dal is maintained during the process of packaging, and it has a long shelf life • Medium dwarf variety 		
Seed rate kg/ha	:	30
Sowing time	:	First week of April
Agronomic practices		

Method of sowing:		
Zero-till mung bean (ZTM)	:	At final wheat harvest, anchored wheat (25-30%) will be kept in the plot under rice-wheat-mung bean cropping system. If sufficient soil moisture is not available in the soil, then apply light irrigation and necessary then also apply Glyphosate (2.5 litre per ha) to knock down the existing perennial weeds. Mung bean seeds will be sown by using the fluted roller seed metering system happy seeder. The seed will be placed at the depth of about 4-6 cm soil depth in a row spacing of 22.5 cm.
Permanent bed mung bean (PBM)	:	After harvesting of mustard crop but keeping about 30-40% crop residue under maize-mustard-mung bean cropping system. Place the mung bean seed and fertilizer two rows on the top of the bed using the disc-type multi-crop bed planter. Maintaining space between two rows is 30 cm.

Nutrient management		
Nitrogen (kg/ha)	:	20
Phosphorus (kg/ha)	:	40
Application	:	Entire dose of N and P will be applied at the time of sowing of the crop.

Irrigation management		
ZTM	:	Flood
PBM	:	Furrow
No. of irrigation	:	2-3 irrigation is applied depending on soil type and moisture condition. Each and every event of irrigation will be recorded and measured for individual plots using the digital flow meter.

Weed management		
ZTM & PBM	:	Pre-plant- If necessary apply Glyphosate (2.5 litre per ha) to knock down the existing perennial weeds.
	:	Post-emergence- Within 25-35 days of sowing applied quizalofop ethy (Targa Super) @ 1ltr/ha.

Observations to be recorded		
No. of plants (sq.m)	:	Count the plants from 2 beds by 4-meter row length
1000 grain weight	:	Count the 1000 grains using the seed counter and weigh 1000 grain weight (g)
Biological yield (t/ha)	:	Mark the area of 2 beds 4-meter row length in case of bed planting 5x5 m in case of flat. Harvest the area and weigh the total biomass and take the sub-sample for moisture determination.
Grain yield (t/ha)	:	Thresh the harvested area as above and record the total grain yield through balance. Take the sub-sample of grain for moisture content.
Protein content analysis	:	Adopted standard method (HAU nutrition scientist will assist and facilitate)
Fat content	:	Adopted standard method for fat estimation (HAU nutrition scientist will assist and facilitate)
Iron content	:	Perkin & Elmer Method
Zinc content	:	Perkin & Elmer Method

SUNFLOWER

Season	:	Spring
Rotations	:	Pearl millet – Pea – Sunflower (ZT-ZT-ZT)
Variety	:	PSH2080/1962 Normal
Variety characteristics		
Crop duration (Days)	:	97 days
Average grain yield (t/ha)	:	2.45 t/ha sun-dried and 2.02 t/ha oven dried
Special characteristics (if any)		
<ul style="list-style-type: none"> • Alternaria leaf spot and powdery mildew resistant variety. • Higher oil contents (43.7%) compared to local cultivars 		
Seed rate kg/ha	:	5
Sowing time	:	For sunflower sowing 15 January to 15 February is the most suitable time.

Agronomic practices

Method of sowing:

After harvest of pea as grain but keeping full pea crop residue and place the sunflower seed and fertilizer on the center of the bed using the disc-type multi-crop inclined plate bed planter. Space between rows 67.5 cm and approximate maintaining the 30cm spacing between two plants.

Nutrient management	
Nitrogen (kg/ha)	: 100
Phosphorus (kg/ha)	: 50
Application	: Entire dose of P and half dose of N is applied at the time of sowing and remaining dose is applied at first irrigation.
Irrigation management	
Irrigation method	: Furrow Irrigation
No. of irrigations	: 4-5 irrigation is applied to sunflower crops. The first light irrigation was applied immediately after sowing to ensure better germination. Second irrigation will be applied 30-35 DAS. Subsequent irrigations should be applied at 12-15 days intervals depending on soil type or irrigation interval adjusted according to soil moisture condition. Each and every event of irrigation will be recorded and measured for individual plots using the digital flow meter.
Weed management	: Pre-plant- If necessary, apply Glyphosate (2.5 litre per ha) to knock down the existing perennial weeds. : Post emergence weed control- One spot hand weeding will be done based on the weed density to remove escaped weeds.
Observations to be recorded	
Plant height at harvest (cm)	: 5 plants, 4 locations each plot
No. of plants at Harvest (sq m)	: Count the number of plants from 2 bed 4-meter row length
Capitulum weight	: Harvest the flower from 5 plants, 4 locations in each plot and weigh the weight
100 grain weight	: Count the 100 grains and record 100 grain weight (g)
Seed yield (t/ha)	: Mark the area of 2 beds 4-meter row length, harvest the capitulum (flower) and weigh the total weight.
Straw yield (t/ha)	: From the marked area after collecting the capitulum, harvest the stover and weigh the total weight.
Protein content analysis	: Adopted standard method (HAU nutrition scientist will assist and facilitate)
Fat content	: Adopted standard method for fat estimation (HAU nutrition scientist will assist and facilitate)
Iron content	: Perkin & Elmer Method
Zinc content	: Perkin & Elmer Method

COWPEA (DUAL PURPOSE)

Season	:	Spring
Rotations	:	Baby Corn – Carrot – Cowpea (dual purpose) (ZT-CT-CT)
Variety	:	UPC 628
Variety characteristics		
Crop duration (Days)	:	Fodder purpose
Average grain yield (t/ha)	:	35.0-42.5 t/ha green fodder and 5.0-5.5 t/ha dry matter
Special characteristics (if any)		
<ul style="list-style-type: none">• Variety has profuse leafy growth with high leaf stem ratio which ensures better quality of the fodder.• Variety has resistance to cowpea yellow mosaic virus, leaf spot, Anthracnose, collar/root rot, aphid, flea beetle and root-knot nematode.• The fodder of this variety has better dry matter digestibility (65-70%) and crude protein content (16-18%).• The pods are medium long (15-17 cm) and tolerant to seed-shattering.		
Seed rate kg/ha	:	20 kg/ha for Seed 30 kg/ha for fodder
Sowing time	:	Second week of march
Agronomic practices		

Land preparation:

After harvesting of the previous carrot crop in the baby corn-carrot-cowpea (dual purpose) system and the plot will be irrigated if sufficient moisture is not available. At the time of appropriate moisture condition the plot will be tilled with cross two harrow and one rotary tiller after that fresh bed prepared using curved/narrow-blade spade raised bed planter.

Method of sowing:

After preparation of field, the sowing of cowpea will be done using zero till fluted roller seed metering system bed planter. Two rows will be sown on the top of the bed. Space between two rows is 30 cm and approximate maintaining the 4-5 cm spacing between plant to plant.

Nutrient management

Nitrogen (kg/ha)	:	15 - 20
Phosphorus (kg/ha)	:	40
Application	:	Full dose of N and P apply at the time of sowing.

Irrigation management

Irrigation method	:	The first light irrigation was applied immediately after sowing in furrows to ensure better germination. Subsequent irrigations should be applied at 10-12 days intervals depending on soil type or irrigation interval adjusted according to soil moisture condition. Each and every event of irrigation will be recorded and measured for individual plots using the digital flow meter.
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Weed management

:	Pre-emergence- Depending on the field access within two-three days of seeding, a pre-emergence herbicide as Pendimethalin (40%) @ 2.5 liter per ha will be sprayed diluting in the 300-350 litre of water. Post emergence weed control- One spot hand weeding will be done 30 DAS based on the weed density to remove escaped weeds.
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Observations to be recorded

Plant height at harvest (cm)	:	5 plants, 4 locations each plot
No. of plant at harvest (sq m)	:	2 bed 4 meter row length
100 grain weight	:	100 grain weight (g)
Pod yield (t/ha)	:	Mark the area of 2 beds 4-meter row length, harvest the green pods in the marked area and weigh the pods weight. There will be multiple harvest, summed each harvest pod weight and record it..
Fodder yield (t/ha)	:	At final harvest of green pods, harvest the total green biomass and weigh the biomass.
Protein content analysis	:	Adopted standard method (HAU nutrition scientist will assist and facilitate)
Fat content	:	Adopted standard method for fat estimation (HAU nutrition scientist will assist and facilitate)
Iron content	:	Perkin & Elmer Method
Zinc content	:	Perkin & Elmer Method

SORGHUM (FODDER)

Season	:	Spring
Rotations	:	Soybean – Wheat – Sorghum (Fodder)
Variety	:	PUSA Chari-9 (Multi-cut Sorghum)
Variety characteristics		
Crop duration (Days)	:	60-65 days
Average grain yield (t/ha)	:	42 t/ha green fodder and 10t/ha dry matter
Special characteristics (if any)		
<ul style="list-style-type: none">• Multi cut variety with high yield of green and dry fodder• Tolerate drought and temporary logging• Withstand in temporary water logging• Tolerant to major insects and pests		
Seed rate kg/ha	:	37.5
Sowing time	:	Last week of April to end of May.
Agronomic practices		
Method of sowing:		
Permanent bed mung bean (PBM)	:	<p>At final wheat harvest, anchored wheat (30%) will be kept in the plot under soybean-wheat-sorghum (fodder) cropping system. If sufficient soil moisture is not available in the soil, then apply light irrigation and necessary then also apply Glyphosate (2.5 litre per ha) to knock down the existing perennial weeds.</p> <p>Place the sorghum seed and fertilizer in two rows on the top of the bed using the disc-type multi-crop bed planter. Maintaining space between two rows is 30 cm</p>
Nutrient management		
Nitrogen (kg/ha)	:	220
Phosphorus (kg/ha)	:	20
Irrigation management		
Irrigation method	:	Furrow Irrigation
No. of irrigations	:	<p>3-4 irrigation is applied depending on soil type and moisture condition. Each and every event of irrigation will be recorded and measured for individual plots using the digital flow meter.</p>

Observations to be recorded

Plant height at harvest (cm)	:	5 plants, 4 locations each plot
		Mark the area of 2 beds 4-meter row length, harvest the green biomass and weight the weight of the total biomass. Take the sub-
Straw Yield	:	sample to estimate the dry biomass.

PEARL MILLET (BAJRA) KHARIF

Season	:	Kharif
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Rotations	:	Pearl millet– Pea– Sunflower (ZT-ZT-ZT)
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Variety	:	Krishna Beej 7711
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Variety characteristics

Crop duration (Days)	:	Medium maturing variety (80 to 85 days)
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Average grain yield (t/ha)	:	4.2 t/ha
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Special characteristics (if any)

- **Long and Semi-compact ear heads.**

- **More no. of tillers**

- **Green till harvest**

- **High gain as well as fodder yield**

Variety	:	HHB 299 Biofortified
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Crop duration (Days)	:	Medium maturing variety (75 to 82 days).
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Average grain yield (t/ha)	:	3.9 t/ha
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Special characteristics (if any)

- **Rich in iron (73.0 ppm) and zinc (41.0 ppm) in comparison to popular varieties/hybrids in this ecology.**

- **Resistant to downy mildew disease.**

Seed rate kg/ha	:	3.75-5
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Sowing Time	:	
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Sow it in the last week of July so that the crop blooms after the monsoon rains, which hinder pollination and lower output.

Agronomic practices

Method of sowing:

After harvesting of sunflower crop and keeping full crop residue under pearl millet-pea-sunflower cropping system and place the pearl millet seed and fertilizer two rows on the top of the bed using the disc-type multi-crop inclined plate bed planter. Seed mix with DAP and drop through fluted roller to ensure uniform distribution in the field. Space between two rows is 30 cm and approximate maintaining the 10-15 cm spacing between plant to plant.

Nutrient management

Nitrogen (kg/ha) : 150

Phosphorus (kg/ha) : 60

Zink sulphate (21%) kg/ha : 25

Application :

Entire dose of P and Zinc at the time of sowing and N is apply in two splits, first split at first irrigation and second split at second irrigation.

Irrigation management

Irrigation method : The supplemental furrow irrigation will be applied as per the rainfall pattern and when a crop needs water in long dry spell between rainfall events. Each irrigation amount of water will be monitored and recorded through the flow water meter.

Weed management : Pre-plant herbicide application will be assessed after the harvest of sorghum fodder crop and if necessary, then apply Glyphosate @ 2.5 litre per ha diluting in 400 litre of water to knock down the existing perennial weeds.
: Post-emergence weed control- One spot hand weeding will be done 30 DAS based on the weed density to remove escaped weeds.

Observations to be recorded

Plant height at harvest (cm) : 5 plants, 4 locations each plot

No. of tillers at harvest (sq m) : Count the number of effective tillers from 2 bed x 4-meter in length

No. of head plant⁻¹ : Count the heads from 5 plants, 4 locations in each plot

Head length : Measure the length of 5 plants at 4 locations in each plot

1000 grain weight : Count the 1000 grains using the seed counter and weigh 1000 grain weight (g)

Biological yield (t/ha) : Mark the area of 2 beds x 4-meter length, harvest the total biomass at harvest, weigh the total biomass and record it. Take the sub-sample for moisture content for dry biomass.

Grain yield (t/ha)	Thresh the harvested biomass, weigh the grain weight and record it. Take the sub-sample of grain for moisture content to adjust the yield at desire moisture.
Stover yield (t/ha)	Subtract the grain yield and husk from dry biological biomass to calculate the stover yield.
Protein content analysis	Adopted standard method (HAU nutrition scientist will assist and facilitate)
Fat content	Adopted standard method for fat estimation (HAU nutrition scientist will assist and facilitate)
Iron content	Perkin & Elmer Method
Zinc content	Perkin & Elmer Method

PEARL MILLET (BAJRA) *SPRING*

Season	Spring
Rotations	Rice-potato-spring pearl millet
Variety	Krishna Beej 7711
Variety characteristics	
Crop duration (Days)	Medium maturing variety (80 to 85 days)
Average grain Yield (t/ha)	4.2 t/ha
Special characteristics (if any)	
<ul style="list-style-type: none"> • Long and Semi-compact ear heads. • More no. of tillers • Green till harvest • High gain as well as fodder yield 	

Variety	HHB 299 Biofortified
Crop duration (Days)	Medium maturing variety (75 to 82 days).
Average grain yield (t/ha)	3.9 t/ha
Special characteristics (if any)	
<ul style="list-style-type: none"> • Rich in iron (73.0 ppm) and zinc (41.0 ppm) in comparison to popular varieties/hybrids in this ecology. • Resistant to downy mildew disease. 	
Seed rate kg/ha	3.75-5
Sowing Time	Sow it in the last week of July so that the crop blooms after the monsoon rains, which hinder pollination and lower output.

Agronomic practices

Land preparation:

After harvesting of the previous potato crop in the rice-potato-pear millet system and the plot will be irrigated if sufficient moisture is not available. At the time of appropriate moisture condition the plot will be tilled with cross two harrow and one rotary tiller after that fresh bed prepared using curved/narrow-blade spade raised bed planter.

Method of sowing:

Place the pearl millet seed and fertilizer two rows on the top of the bed using multi-crop bed planter. Seed mix with DAP and drop through fluted roller to ensure uniform distribution in the field. Space between two rows is 30 cm and approximate maintaining the 10-15 cm spacing between plant to plant

Nutrient Management

Nitrogen (kg/ha) 150

Phosphorus (kg/ha) 60

Zinc sulphate (21%) kg/ha 25

Application

Entire dose of P and Zinc at the time of sowing and N is apply in two splits, first split at first irrigation and second split at second irrigation.

Irrigation method

Furrow Irrigation

No. of irrigations

4-5 irrigation is applied depending on soil type and moisture condition. Each and every event of irrigation will be recorded and measured for individual plots using the digital flow meter.

Weed management

Pre-emergence- Depending on the field access within two-three days of seeding, a pre-emergence herbicide as Pendimethalin (40%) @ 2.5 liter per ha will be sprayed diluting in the 300-350 litre of water.

Post emergence weed control- One spot hand weeding will be done 30 DAS based on the weed density to remove escaped weeds.

Observations to be recorded

Plant height at harvest (cm) 5 plants, 4 locations each plot

No. of tillers at harvest (sq m) Count the number of effective tillers from 2 bed x 4-meter in length

No. of head plant⁻¹ Count the heads from 5 plants, 4 locations in each plot

Head length	Measure the length of 5 plants at 4 locations in each plot
1000 grain weight	Count the 1000 grains using the seed counter and weigh 1000 grain weight (g)
Biological yield (t/ha)	Mark the area of 2 beds x 4-meter length, harvest the total biomass at harvest, weigh the total biomass and record it. Take the sub-sample for moisture content for dry biomass.
Grain yield (t/ha)	Thresh the harvested biomass, weigh the grain weight and record it. Take the sub-sample of grain for moisture content to adjust the yield at desire moisture.
Stover yield (t/ha)	Subtract the grain yield and husk from dry biological biomass to calculate the stover yield.
Protein content analysis	Adopted standard method (HAU nutrition scientist will assist and facilitate)
Fat content	Adopted standard method for fat estimation (HAU nutrition scientist will assist and facilitate)
Iron content	Perkin & Elmer Method
Zinc content	Perkin & Elmer Method

AUTHORS

Love Kumar Singh, Research Associate
Hanuman Sahay Jat, Principal Scientist, ICAR-CSSRI
Deepak Bijarniya, Senior Research Associate, CIMMYT
Raj Mukhopadhyay, Scientist, ICAR-CSSRI
Madhu Choudhary, Sr. Scientist, ICAR-CSSRI
Manish Kumar, Research Associate, CIMMYT
Stephanie Cheesman, Cropping Systems Agronomist, CIMMYT
Mahesh Kumar Gathala, Senior Systems Agronomist, CIMMYT
Mangi Lal Jat, Principal Scientist, CIMMYT
Prabodh Chandra Sharma, Director, ICAR-CSSRI
Timothy Krupnik, Country Representative for Research and Partnerships and Systems Agronomist, CIMMYT

SUGGESTED CITATION

Singh, LK., Jat, HS., Bijarniya, D., M., Mukhopadhyay., R. Choudhary, M., Kumar, M., Cheesman, S., Gathala, M.K., Jat, M.L., Sharma, PC., Krupnik, T.J. 2022. Diverse and healthy cropping systems trial protocol. Work Package 2 Research Protocol 4. CGIAR research initiative on Transforming Agrifood Systems in South Asia (TAFSSA). International Maize and Wheat Improvement Center. Dhaka, Bangladesh.

FUNDING ACKNOWLEDGEMENT

We would like to thank all funders who supported this research through their contributions to the CGIAR Trust Fund: <https://www.cgiar.org/funders/>

To learn more, please contact: m.gathala@cgiar.org

To learn more about TAFSSA, please contact:
t.krupnik@cgiar.org; p.menon@cgiar.org

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TAFSSA is a CGIAR regional integrated initiative to support actions that improve equitable access to sustainable healthy diets, improve farmers' livelihoods and resilience, and conserve land, air, and water resources in South Asia.

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