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On-farm Assessment of Site Specific Nutrient Management in Rainfed areas of Telangana

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ABSTRACT

Fertilizer use immensely contributes to higher crop productivity and ensuring food security around the globe, but excess application of nitrogenous fertilizers resulted in negative environmental externalities in the world. Thus assessing imbalances in chemical fertilizer use is vital for environmental sustainability, and this on-farm trial was conducted to study the pattern of nutrient imbalances due to imbalanced chemical fertilizer application. This on-farm assessment of Site-Specific Nutrient Management (SSNM) through yield target approach was conducted with different test crops viz., rice, maize, ragi, groundnut, sesamum, green gram, black gram, jonna, bajra and castor in Nagarkurnool district during rabi season. The results revealed that the targeted yield prescription equations with SSNM approach increased percent yield as 35.67 in rice, 28.80 in ragi, 34.24 in maize, 33.70 in groundnut, 27.62 in sesamum, 23.14 in green gram, 21.32 in black gram, 23.60 in bajra, 26.76 in jonna, 29.54 in castor crops to ensure higher seed yield, as well as nutrient response ratio to the applied fertilizers over the farmers' practice. The seed yield from the pre-fixed target yields were achieved within ± 15% yield deviation at all the locations of farmer fields. The targeted yield prescription models along with SSNM fertilizer recommendations were more precise to achieve the targeted yield of various crops grown in rainfed areas of Telangana for higher profits by conserving soil health.

Keywords: *Target yield, site specific nutrient management, soil test crop response and on-farm trials*

INTRODUCTION

From the green revolutionary period 1969 to 2022, the food grain production more than doubled from 98 million ton (Mt) to a record of 316 Mt in 2021-22, while the fertilizer nutrient consumption increased from 16.6 kilograms per hectare in 1971 to 209.4 kilograms per hectare in 2020 growing at an average annual rate of 5.70%. Over the past few decades, the crop management in India has been driven by an increasing use of external application of fertilizer inputs. Further, these fertilizer nutrients have impacted the production costs with serious environmental consequences. Recent research [5] has demonstrated the limitations in blanket fertilizer recommendations practicing across the Asian countries. On-farm research has clearly demonstrated the existence of large field variability in soil nutrient supply, nutrient use efficiency and crop responses. Thus, it was hypothesized that future gains in productivity and input use efficiency will require soil and crop management technologies that are knowledge-intensive and tailored to specific characteristics of individual farms or fields to manage the variability among and within the fields [22].

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The soils of the rainfed regions are not only thirsty but are also hungry, in this area's soils are low to medium in organic carbon, and are coarse to medium in texture, and low in biological activity. Soil erosion with depletion of nutrients under continuous cropping without adequate additions of organic nutrients over the years has resulted in the degradation of soils. Wide-spread deficiencies of macro, micro and secondary nutrients have been reported in the rainfed areas [6], and these must be overcome through balanced nutrition of crops. But the appropriate fertilization strategies are recurrent challenge for farmers before and during each cropping period. The main drawback of blanket fertilizer recommendations is their failure to account for the high spatial soil fertility variability that is common in smallholder farming systems [9]. Such variability has been linked to inherent soil fertility differences, or differences induced by management practices [15]. Consequently, the blanket fertilizer recommendations, nutrients can be applied in excess or inadequately for different locations which further reduce the efficient utilization of applied nutrients. Excess application of nutrients can lead to nutrient leakages to the environment resulting in adverse environmental impacts such as pollution of surface and ground waters. In this scenario, alternative integrated soil fertility management practices are needed to restore depleted soils, and to ensure long-term environmental and crop production sustainability. In rainfed farming systems, yield response to fertilizer application is usually poor in sandy soils [1] highlighting the need for customized fertilizer recommendations.

A focus on agronomically based nutrient application rates can be misleading the interaction among indigenous sources and applied inputs which further lead to soil health related issues. These issues are also critical in the decision-making processes of farmers, scientists and policymakers in the rainfed areas of world which has significant implications for food security through the global market. An opportunity exists to increase nutrient use efficiency through balanced and more precise plant nutrition to enhance food production and protect environmental resources. Optimizing crop productivity will depend on flexible fertilizer management practices tailored to spatial variation to ensure optimum nutrient use to avoid under- or over-supply of nutrients in crop fields. Site-Specific Nutrient Management (SSNM) strategy is an alternative approach for dynamic management of nutrients to optimize the supply and demand of a nutrient within a specific field in a particular cropping season, as compared to other fertilizer recommendations which were often derived from factorial fertilizer trials conducted across multiple locations. The SSNM strategy offers proper timing and splitting patterns for fertilizer applications using a location-specific nutrient status to utilize indigenous nutrients and optimize fertilizer doses to maximize crop yield [3]. Keeping this in view, the present study examines the extent of nutritional constraints and the scope of Site-Specific Nutrient Management (SSNM) approach on productivity enhancement and livelihood improvement of farmers in dry land areas of Telangana.

MATERIALS AND METHODS

A total of ten on-farm trials were conducted with different test crops viz., rice, maize, ragi, groundnut, sesamum, green-gram, black-gram, jonna, bajra and castor in Nagarkurnool district during rabi season with the objective to demonstrate the comparative evaluation of site-specific nutrient management (SSNM) with target yield approach, blanket application of recommended fertilizers, soil test crop response (STCR) equation and farmer's practice. After conducting farmers' meeting in each village, and depending upon soil type, crop, slope and management practices, farmers' fields were selected using stratified random methodology for demonstration of soil sampling procedure in one hectare. Soil samples from farmers' fields covering ten villages were collected with farmer participation in soil sampling, and collected soil samples were labeled with cluster name, village name and farmer's name. The soil pH was measured by glass electrode using a soil to water ratio of 1:2, and electrical conductivity (EC) was determined by an EC meter using a soil to water ratio of 1:2. The organic carbon (OC) was determined using the Walkley-Black method [14]. The available N was determined by alkaline permanganate method [24], whereas available P was determined by sodium bicarbonate (0.5N $NaHCO_3$) extractant at pH 8.5 [16]. The available K analyzed with neutral normal ammonium acetate method [7], available S was measured using 0.15% calcium chloride ($CaCl_2$) solution as an extractant [25], available micronutrients (Zn, Fe, Cu and Mn) were extracted by DTPA reagent [13] and available B was extracted by hot water [10] at soil chemistry laboratory of Regional Agricultural Research Station, Palem, Nagarkurnool district of Telangana. Further, crops were grown on selected farmers' fields with known fertility status by using SSNM based nutrient application with yield target fertilizer prescription equations. The balanced nutrition included a recommended dose of fertilizer nutrients as N: P_2O_5: K_2O (kg acre-1) of 60:24:16 for rice, 25:14:8 for ragi, 96:32:32 for maize, 8:16:19 for groundnut, 24:8:8 for sesamum, 18:23:10 for green gram and black gram, 36:16:16 for bajra, 40:24:16 for jonna and 32:16:12 for castor. Farmer's practice in each trial was documented, which included suboptimal doses of N and P. Besides fertilizer management, other crop management practices like weeding and pest and disease control measures were followed, and the data on crop yield was analyzed considering farmers as replications using one way ANOVA with randomized blocks on Bluestat.

RESULTS AND DISCUSSION

Physico-chemical (pH, EC and Organic carbon) properties

Fertility status of different locations presented in Table 1. The soils are slightly acidic to strongly alkaline (pH 6.04 to 8.68) in reaction with an overall mean of 8.00. Among the analyzed samples, 2.71% of soils found as moderately to slightly acidic, 7.53% samples in neutral range, 74.49% area under moderately alkaline status and 15.27% of soils with strongly alkaline in reaction. The electrical conductivity of the studied area varied from 0.07 to 0.42 dS m-1 with a mean of 0.22 dS m-1 which indicated selected locations of Southern Telangana Zone remains within safe limit with no salinity hazard (<2.00 dSm-1). Organic carbon content of different locations varied widely among villages, and from varied from 0.27 to 0.43 with a mean of 0.37 percent. While characterizing the soil samples representing from major rainfed production systems of Southern Telangana Zone [17] reported that most of the soil profiles were low in organic carbon, and this might be due to warm arid climate which decomposes of added materials rapidly.

Available Major (N, P and K) Nutrient Status

Organic matter is the major source of nitrogen (N) in soils, but the rainfed soils are poor in organic matter and automatically are deficient in N. The available nitrogen status among the farmer's fields ranged from 87.81 to 193.79 kg ha-1 with an overall mean value of 132.68 kg ha-1, which indicating entire soils were too low i.e., <200 kg of available nitrogen ha-1 than the critical limit (<280 kg available nitrogen ha-1). Among the locations, highest percentage of low available N status (100%) was recorded, and this low level of soil N is attributed primarily as inappropriate management options coupled with high temperature and aerated conditions facilitated ammonia volatilization, leaching, runoff and de-nitrification [1]. The available phosphorus (P_2O_5) ranged from 28.11 to 89.03 kg ha-1 with a mean value of 55.40 kg ha-1, which indicating medium to high availability of phosphorus at farmer's field. The continuous application of phosphatic fertilizers without knowing its availability in the soil might be the reason for high phosphorus content in the alkaline soils of farmer's fields. Among the samples analyzed, 58.3% of soils in medium range, 37.4.33% of farmers' fields pose high phosphorus, and 4.3% of soils were in very high content of available phosphorus because of immobile nature of the nutrient in the soil system. The available potassium (K_2O) content ranged from 471.36 to 696.19 kg ha-1 with a mean value of 600.04 kg ha-1 (Table. 1), also highest percentage of available potassium status (100%) observed in farmers' fields (Table 1) because of concomitant increase in interstratified minerals and lower mining of the element, which exists in the crop-lands as K^+ forms to involve in physiological processes of plant metabolism [3].

Available Sulphur (mg kg-1) status

The available sulphur (S) ranged from 4.05 to 8.71 mg kg-1 with an overall mean of 5.86 mg kg-1 indicating the entire study area was in deficient status (Table.1), because of its content and availability largely determined by the organic matter level of the particular soils. Further, sulphur is reported to be deficient in a vast majority of the dry land soils [23]. At the study area, 32.5% of samples registered too low sulphur content (<5 mg kg-1), and 67.5% of samples found in low status of its categorization (<10 mg kg-1). Further, intense cultivation of crops without applying sulphur-containing fertilizers might cause available sulphur deficiency in the farmer fields which is very essential for plant growth, and is an integral part of proteins, phyto-chelatins, chloroplast membrane, and certain co-enzymes and vitamins [26].

Available Micronutrients (Zn, Cu, Fe, Mn and B) status

The available zinc (Zn) content ranged from 0.41 to 4.62 mg kg-1 with a mean value of 1.73 mg kg-1 as represented in Table (1), and is an essential element which associated with chlorophyll development in leaves [8]. At the study area, 94.99% samples had more than 0.60 mg kg-1 Zn content of its critical level which indicates its sufficiency, and 5.01% of soils were insufficient in available zinc. Available copper (Cu) in the study area varied from 0.12 to 4.69 mg kg-1 with an average value of 1.78 mg kg-1 as presented in Table (1), and entire soils registered >0.20 mg kg-1 of available copper content which indicating that the entire analyzed soil samples had sufficient status of available copper. The available iron (Fe) content in the farmers' fields were ranged from 4.30 to 9.41 mg kg-1 with an average of 6.75 mg kg-1 as depicted in Table. (1), and it plays an important role in various metabolic processes [18]. Soils of farmer's fields recorded > 4.00 mg kg-1 of available Fe content of its critical level and showed sufficiency status, which also plays an essential role in DNA synthesis, respiration, and photosynthesis [11]. The available manganese (Mn) content ranged from 10.92 to 30.63 mg kg-1 with an average of 21.05 mg kg-1 as presented in Table (1). The entire study area registered >2.00 mg kg-1 of available Mn content of its critical level, which showed excess content in the soil. The available boron (B) content of the study area ranged from 0.16 to 0.44 mg kg-1 with an average of 0.33 mg kg-1 as presented in Table. (1), which enhances the development of reproductive parts and carbohydrate metabolism. At the study area, entire samples were found in low status of its categorization (0.52 mg kg-1) due to low organic carbon content which greatly affects the absorption of boron at the study area [21].

The yield of test crops (q ha-1) obtained at different locations ranged widely presented in Fig.1 to Fig.10. Important rabi crops (rice, maize, ragi, groundnut, sesamum, green-gram, black-gram, jonna, bajra and castor) of Nagarkurnool district showed significant response to SSNM compared to blanket application of recommended fertilizers, soil test crop response (STCR) equation and farmers practice in all the locations. The seed yield (q acre-1) increased from 16.09-25.83 in rice, 24.58-31.66 in ragi, 26.14-35.09 in maize, 9.02-12.06 in groundnut, 1.81-2.31 in seamum, 2.90-3.57 in greengram, 4.41-5.35 in blackgram, 5.17-6.39 in bajra, 13.60-17.24 in jonna and 16.08-20.83 in castor crop due to variation in the crop response to the balanced nutrition which was wide among farmers' fields. The deficiency and excess of soil nutrients in agricultural fields can be due to the inherent deficiency or toxicity and mining of nutrients by crop cultivation [2]. Therefore, farmers should follow most appropriate techniques to apply fertilizers after soil testing. The lower seed yield (q acre-1) registered in farmers practice as 16.09 in rice, 24.58 in ragi, 26.14 in maize, 9.02 in groundnut, 1.81 in seamum, 2.90 in greengram, 4.41 in blackgram, 5.17 in bajra, 13.60 in jonna and 16.08 in castor crops because of imbalanced and inadequate doses of fertilizer applications among the farmers' fields, and particularly they are using excessive doses of nitrogenous fertilizers which is the most crucial soil nutrient for environmental sustainability, as well as to maintain imbalance index of nutrients in soil system. The divergence from ideal NPK ratio is not healthy for cropping systems, and fertilizer management practices can impact the long-term sustainability of cultivable land and food security [4]. Target yield-based site-specific nutrient management approach registered highest yields (q acre-1) viz., 21.83 in rice, 31.66 in ragi, 35.09 in maize, 12.06 in groundnut, 2.31 in seamum, 3.57 in greengram, 5.35 in blackgram, 6.39 in bajra, 17.24 in jonna and 20.83 in castor. Further, the results revealed that the percent yield increased as 35.67 in rice, 28.80 in ragi, 34.24 in maize, 33.70 in groundnut, 27.62 in sesamum, 23.14 in green gram, 21.32 in black gram, 23.60 in bajra, 26.76 in jonna, 29.54 in castor crops over farmers practice due to more precise application of fertilizers in the study area, the balanced use of macro and micro-nutrients should be the way forward for nutrient management [12]. Management practices such as site-specific nutrient management (SSNM) is the most accurate technology to apply fertilizers and to improve crop yield and reduce excess use of fertilizers [20].

CONCLUSION

External application of soil nutrients is essential for crop productivity and nutrition security, but the excessive and imbalanced use of chemical fertilizers poses an environmental threat. A low soil nutrient supplementation and continuous mining through cultivation can also lead to soil degradation. Excessive and deficient application of fertilizers can impact the long-term sustainability of cultivable land and food security. Hence, we have studied the spatial distribution of nutrients and imbalances in fertilizer application in different villages of Nagarkurnool district, Telangana. Soil nutrient management practices evolve temporally and spatial differences in fertilizer application are equally valid to find environmental Kuznets curves to know nitrogen use efficiency and balance sheet over time. Balanced use of macro- and micro-nutrients should be the way forward for nutrient management, and management practices such as site-specific nutrient management (SSNM) is to improve crop yield and to reduce excess use of fertilizers. By adopting SSNM and balanced nutrition approach over the farmer's practice, yield levels were increased as 35.67 in rice, 28.80 in ragi, 34.24 in maize, 33.70 in groundnut, 27.62 in sesamum, 23.14 in green gram, 21.32 in black gram, 23.60 in bajra, 26.76 in jonna, 29.54 in castor crops. The results from the current study clearly bring out the potential of SSNM and balanced nutrition in enhancing crop productivity and sustainability to improve farmer's income in rural areas. Further, Indian government designed the soil health card scheme to promote SSNM, and it is a promising ongoing programme to encourage balanced fertilizer application. However, there is much need to strengthen the extensions activities to educate farmers about fertilizer recommendations based on soil health card indicators.

Table 1: Initial soil fertility status of farmers field's at Nagarkurnool District

Location	Treat-ment	pH	EC (dSm^{-1})	OC (%)	Ava. N	Ava. P_2O_5	Ava. K_2O	Ava.S	Zn	Cu	Fe	Mn	B
					($kg\ ha^{-1}$)			($mg\ kg^{-1}$)					
Location-I	FP	8.40	0.31	0.43	125.09	42.17	594.05	4.94	1.79	2.34	9.40	26.83	0.25
	RDF	8.16	0.36	0.42	150.18	51.54	654.53	5.73	1.05	1.29	7.04	20.61	0.30
	STCR	8.28	0.41	0.36	150.53	65.60	676.03	6.69	1.94	3.18	8.13	11.09	0.30
	SSNM-4	8.31	0.30	0.43	112.90	46.86	611.52	4.94	1.25	2.44	5.70	19.62	0.39
Location-II	FP	6.04	0.11	0.42	117.81	51.54	600.77	8.44	0.52	1.08	6.50	13.05	0.30
	RDF	6.61	0.10	0.35	112.54	60.91	571.20	5.15	1.17	1.20	6.25	16.10	0.20
	STCR	6.84	0.15	0.39	87.81	56.23	555.07	5.11	1.49	1.43	5.69	28.82	0.16
	SSNM-4	8.20	0.23	0.42	112.90	46.86	576.58	4.94	2.37	2.24	4.30	28.69	0.25
Location-III	FP	8.62	0.26	0.42	188.16	60.91	691.58	6.69	3.49	3.01	9.35	19.81	0.39
	RDF	8.58	0.24	0.30	100.35	51.54	626.30	6.69	4.59	3.32	5.73	29.93	0.30
	STCR	8.68	0.30	0.43	188.16	51.54	659.90	5.61	1.04	3.03	8.31	10.92	0.20
	SSNM-4	8.49	0.24	0.36	100.35	42.17	657.22	4.94	1.19	1.01	5.10	11.57	0.30
Location-IV	FP	8.54	0.25	0.36	100.35	60.91	573.89	8.44	1.45	2.01	7.62	22.72	0.30
	RDF	8.59	0.19	0.39	171.79	51.54	696.19	6.69	1.98	4.69	5.50	24.05	0.39
	STCR	8.41	0.24	0.43	125.44	60.91	614.21	5.74	1.35	2.06	8.23	30.63	0.25
	SSNM-4	8.54	0.26	0.42	175.62	51.54	571.20	4.06	1.33	1.94	7.90	20.71	0.35
Location-V	FP	8.30	0.39	0.39	193.79	65.60	637.82	4.94	1.81	0.48	6.39	12.29	0.25
	RDF	8.28	0.42	0.36	150.53	46.86	654.53	5.05	1.29	1.92	6.70	28.47	0.30
	STCR	8.22	0.21	0.42	107.81	56.23	620.93	7.63	1.69	2.18	5.40	24.27	0.39
	SSNM-4	8.38	0.38	0.42	137.98	74.97	649.15	5.21	2.29	0.91	7.31	14.11	0.30
Location-VI	FP	8.02	0.13	0.27	102.72	56.23	628.99	4.94	2.51	1.24	6.79	26.69	0.35
	RDF	8.28	0.12	0.36	150.53	37.49	631.68	5.61	1.77	1.59	5.30	19.61	0.25
	STCR	8.05	0.14	0.42	137.98	74.97	511.78	5.53	2.07	1.10	8.20	23.85	0.30
	SSNM-2	7.72	0.13	0.39	137.98	28.11	676.54	7.56	1.59	2.97	6.51	29.24	0.44
Location-VII	FP	7.96	0.28	0.30	112.90	89.03	513.66	4.94	0.41	1.30	5.39	26.17	0.39
	RDF	8.22	0.24	0.27	125.44	42.17	629.94	4.06	1.14	0.71	5.72	14.94	0.30
	STCR	7.93	0.20	0.39	105.26	28.11	619.58	4.94	1.19	0.55	8.47	22.05	0.16
	SSNM-4	8.17	0.20	0.27	190.70	28.11	478.18	6.69	1.71	1.55	6.19	29.91	0.35
Location-VIII	FP	7.62	0.13	0.36	112.90	37.49	658.56	6.69	1.12	1.12	6.70	16.35	0.35
	RDF	8.23	0.15	0.42	125.09	70.29	529.79	4.94	1.04	0.12	4.60	11.15	0.41
	STCR	8.20	0.12	0.36	112.90	74.97	598.08	4.05	1.23	0.50	6.74	15.48	0.25
	SSNM-4	7.78	0.07	0.30	100.35	74.97	638.62	4.94	1.79	2.34	9.40	26.83	0.25
Location-IX	FP	8.22	0.24	0.30	125.44	79.66	531.94	6.96	4.62	1.93	9.41	29.26	0.37
	RDF	7.37	0.09	0.43	125.09	89.03	693.50	5.21	1.07	2.19	7.05	19.34	0.27
	STCR	7.59	0.07	0.36	150.18	37.49	569.86	8.71	1.22	0.92	8.14	10.92	0.32
	SSNM-4	7.66	0.21	0.36	112.72	70.29	662.59	5.42	1.48	1.25	5.71	27.10	0.41
Location-X	FP	7.93	0.21	0.31	121.96	53.80	517.06	5.38	2.01	1.60	6.51	22.90	0.32
	RDF	8.13	0.15	0.40	135.14	39.85	487.49	5.21	1.38	1.11	6.26	12.74	0.37
	STCR	7.62	0.12	0.37	112.64	63.71	471.36	6.96	1.36	2.98	5.7	25.32	0.27
	SSNM-4	8.27	0.23	0.39	183.04	37.46	492.87	6.96	1.84	1.31	4.31	18.24	0.32

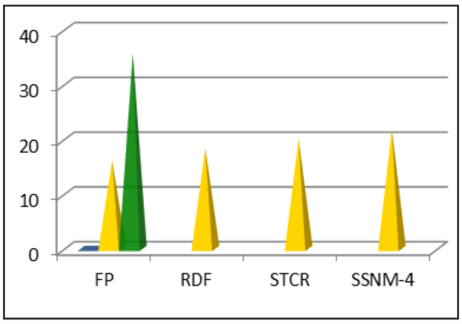

Fig.1: Rice yield (q acre-1) at Location-I

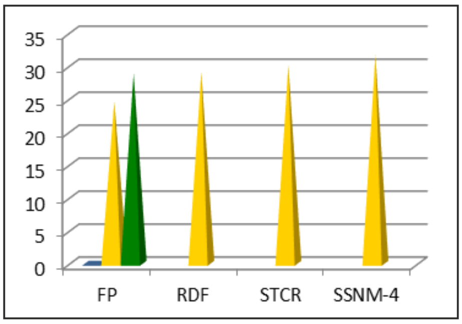

Fig.2: Ragi yield (q acre-1) at Location-II

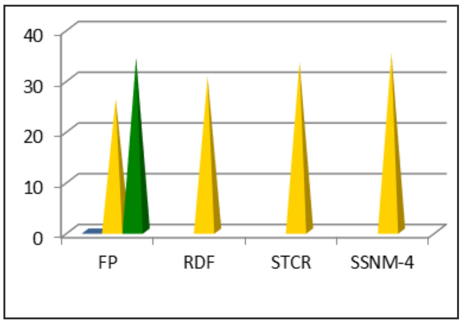

Fig.3: Maize yield (q acre-1) at Location-III

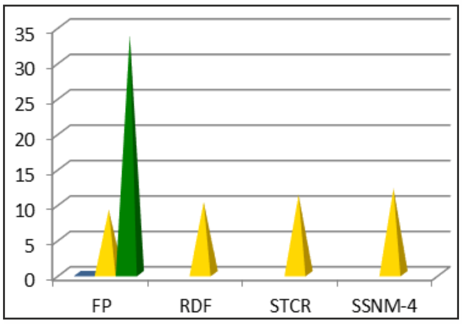

Fig.4: Groundnut yield (q acre-1) at Location-IV

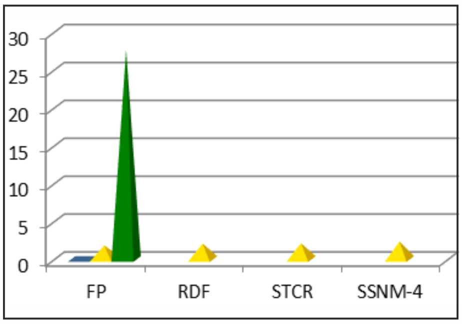

Fig.5: Sesamum yield (q acre-1) at Location-V

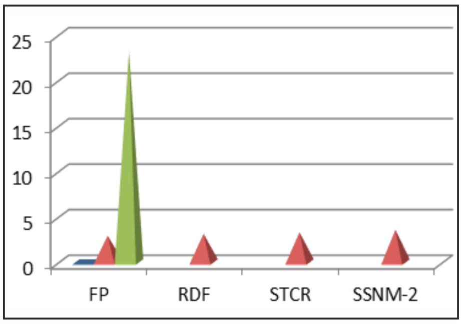

Fig.6: Greengram yield (q acre-1) at Location-VI

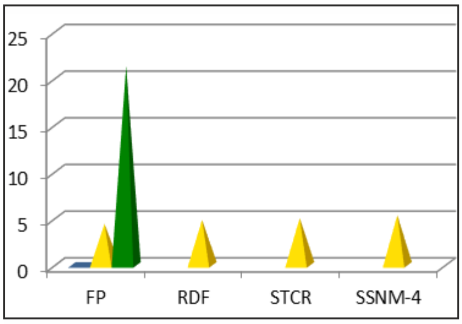

Fig.7: Blackgram yield (q acre-1) at Location-VII

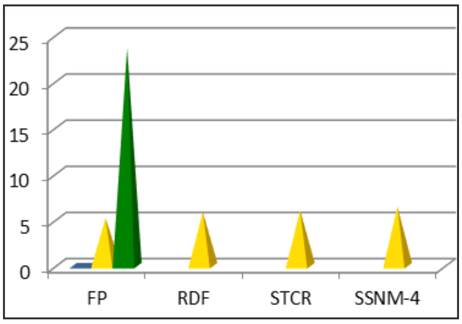

Fig.8: Bajra yield (q acre-1) at Location-VIII

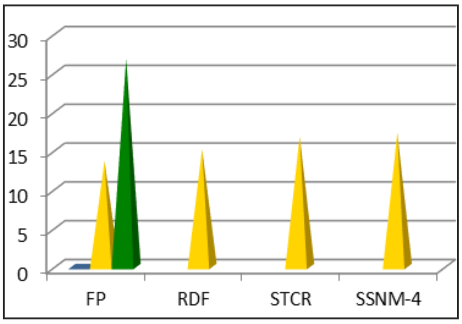

Fig.9: Jonna yield (q acre-1) at Location-IX

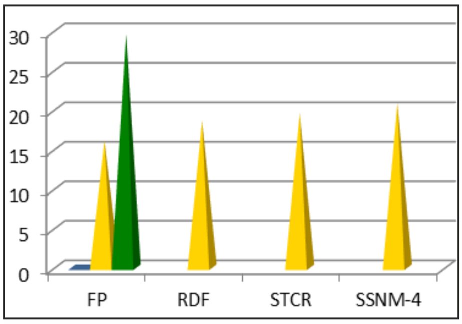

Fig.10: Castor yield (q acre-1) at Location-X

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