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EFFECT OF CROP ESTABLISHMENT METHODS, RESIDUE AND NUTRIENT MANAGEMENT ON FODDER YIELD AND QUALITY IN MAIZE-WHEAT CROPPING SYSTEM

SUMIT BHARDWAJ*[1], NAVEEN KUMAR[2], JHABAR MAL SUTALIYA[3], KRISHAN KUMAR BHARDWAJ[4] AND SATPAL[5]

[1]Department of Agronomy, CCS Haryana Agricultural University, Hisar-125004 (Haryana), India
[2] Regional Research Station, CCS Haryana Agricultural University, Hisar-125004 (Haryana), India
[3]MAP Section (GPB), CCS Haryana Agricultural University, Hisar-125004 (Haryana), India
[4]Department of Soil Science, CCS Haryana Agricultural University, Hisar-125004 (Haryana), India
[5]Department of G & PB (Forage Section), CCS Haryana Agricultural University, Hisar-125004 (Haryana), India
**(e-mail : sumitbhardwaj909@hau.ac.in)*

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SUMMARY

The present study was conducted during 2022-23 and 2023-24 at research farm, Department of Agronomy, CCS Haryana Agricultural University, Hisar. The experiment consisted of four crop establishment methods and residue management treatments in main plots (T_1: Conventional Tillage without residue incorporation (CT-R), T_2: Conventional Tillage with residue incorporation (CT+R), T_3: Zero Tillage-Permanent beds without residue retention (PB-R), T_4: Zero Tillage- Permanent beds with residue retention (PB+R) and five nutrient management treatments in sub-plots (F_1: 75% RDF, F_2: 87% RDF, F_3: 100% RDF, F_4: 113% RDF, F_5: 125% RDF) accommodated in split plot design with three replications. The dry matter accumulation in PB+R at 60 DAS (444.8 and 455.9 g/m.r.l.), 90 DAS (695.2 and 707.8 g/m.r.l.) and at harvest (805.5 and 819.8 g/m.r.l.) was significantly higher than other crop establishment methods except for PB-R during 2022 and 2023, respectively. Among nutrient management treatments, the maximum dry matter accumulation was found with 125% RDF at 30 DAS (191.6 and 196.6 g/m.r.l.), 60 DAS (437.5 and 442.8 g/m.r.l.), 90 DAS (681.5 and 688.7 g/m.r.l.) and at harvest (788.4 and 811.8 g/m.r.l.) during 2022 and 2023, respectively. The stover yield of maize was significantly higher under PB+R (8788 and 10423 kg/ha) as compared to CT+R and CT-R during 2022 and 2023, respectively. Among different nutrient management treatments, the highest stover yield was obtained with 125% RDF (8554 and 9779 kg/ha). The maximum dry matter accumulation of wheat was recorded under PB+R at 60 DAS (44.9 and 48.1 g/mrl), 90 DAS (207.0 and 222.7 g/mrl), 120 DAS (324.5 and 346.6 g/mrl) and harvest (333.5 and 355.4 g/mrl) during 2022-23 and 2023-24, respectively. Among crop establishment methods and residue management, the maximum straw yield was found with PB+R (6852 and 7007 kg/ha) during 2022-23 and 2023-24, respectively which was significantly higher than CT+R (5820 and 6203 kg/ha) and CT-R (5553 and 5647 kg/ha) during 2022-23 and significantly higher than all the other treatments during 2023-24. It was recorded maximum with 125% RDF (6455 and 6544 kg/ha) which significantly outyielded all other treatments except 100 and 113% RDF during 2022-23 and 2023-24, respectively.

Key words: Fodder productivity, protein content, quality, nutrient management, crop establishment

After rice-wheat and rice-rice cropping systems, Maize-wheat is the third most important cropping system in the world and it is first among maize-based cropping systems occupying 1.8 million hectares area, contributing 3% in the food grain production of the country (Mal and Chaudhary, 2023). The total production of maize in India was 35.6 million tonnes from an area of 11 million hectares during 2023-24. While, the production of wheat was 113 million tonnes from an acreage of 34 million hectares during 2023-24 (DA&FW India, 2024). In Haryana, the area under maize was 4.98 thousand hectares which gave a production of 18.35 thousand tonnes with a productivity 36.85 q/ha during *kharif* 2023. The area, production and productivity of wheat in Haryana were 2376 thousand hectares, 11064 thousand tonnes and 46.55 q/ha, respectively during *rabi* 2022-23 (DoA&FW Haryana, 2024). Conservation agriculture-based agronomic management options such as permanent beds and residue management in maize-

wheat cropping system are reported to yield higher, saves water & labour and improve soil quality (Gathala *et al*., 2013; Jat *et al.,* 2015; Hasanain *et al.,* 2021). Nutrient management plays a significant role in attaining higher crop production (Baweja *et al*., 2020). However, inappropriate use of inorganic fertilizer not only affects productivity and soil health (Singh, 2024) but also has many environmental impacts like leaching of nutrients, soil acidification, ground and surface water pollution, eutrophication and increased levels of greenhouse gases emissions (Romero *et al*., 2021; Amin and Jilani, 2024). The nutrient availability and uptake from crop residue retained or incorporated in the soil is affected by various processes like mineralization, immobilization, leaching etc. Liu *et al*. (2017) based on their study in maize-wheat cropping system suggested that the conventional rate of N fertilization (240 kg/ha) is excessive and poses a major risk of groundwater contamination due to NO_3-N leaching, while the N-120 kg/ha and N-240 kg/ha treatments were statistically at par in terms of crop yield, water productivity and N uptake. Thus, keeping in view the above aspects, an attempt has been made to study the effect of crop establishment methods, residue and nutrient management on fodder yield and quality in maize-wheat cropping system.

MATERIALS AND METHODS

The study was carried out at the research farm, Department of Agronomy, CCSHAU, Hisar, Haryana, India during 2022-23 and 2023-24. The research farm is located at 29°10' N latitude, 75°46' E longitude and an altitude of 215 m above mean sea level. The site's climate is sub-tropical and semi-arid which may be categorised as BSh type as per Koppen and Gendiger climate classification. It has very hot summers (with temperature reaching up to 45 °C or more) and bitterly frigid winters (with lows of 2-3 °C or even less). The warmest months of the region are May and June, while the coldest months are December and January during which frost may also occur. The site has mean annual temperature of 25.3 °C and precipitation of 400-450 mm. The minimum average daily pan evaporation at the site is found in January (1.3 mm) and the maximum in June (12.9 mm). The site's soil was found alkaline in nature and sandy loam in texture. It had 0.37% organic carbon (low), 114.2 kg $KMnO_4$ oxidizable N/ha (low), 13.6 kg 0.5N $NaHCO_3$ extractable P/ha (medium), 285.3 kg 1N NH_4OAc exchangeable K/ha (high), 0.32 dS/m EC, 7.96 pH and 1.58 Mgm^{-3} bulk density at the start of experiment. The split plot design was used to set up the experiment, with four crop establishment methods and residue management treatments in the main plots and five nutrient management treatments in the subplots. The number of replications was three. The details of treatments are as follows: Main plots: Crop establishment methods T_1: Conventional Tillage without residue incorporation (CT-R), T_2: Conventional Tillage with residue incorporation (CT+R), T_3: Zero Tillage-Permanent beds without residue retention (PB-R), T_4: Zero Tillage-Permanent beds with residue retention (PB+R); Sub-plots: Nutrient management F_1: 75% RDF, F_2: 87% RDF, F_3: 100% RDF, F_4: 113% RDF, F_5: 125% RDF. The RDF (Recommended dose of fertilizers) was 150 kg N/ha, 60 kg P_2O_5/ha, 60 kg K_2O/ha, 25 kg $ZnSO_4$/ha for both crops.

The field was prepared with two harrowing along with two ploughings followed by planking as preparatory tillage for ridge sowing in conventional tillage. In CT, maize was sown on the conventional ridges which were formed with the help of tractor operated ridger at a distance of 60 cm. In PB plots, raised beds were formed with the help of a raised bed planter three months before the start of the experiment. The distance from top-middle of one bed to adjacent was maintained 60 cm. No-tillage operation was carried out in PB plots, only reshaping of beds was performed during the sowing of succeeding crops in both years. Round up (Glyphosate 41% SL) was applied on the permanent raised beds plots before sowing of crops in 2022-23 and 2023-24, respectively to knock down the weeds. The wheat was sown on flat land in conventional method and on permanent beds in PB plots.

RESULTS AND DISCUSSION

Dry matter accumulation of Maize

The data related to dry matter accumulation of maize is shown in Table 1. The dry matter accumulation increased continuously with the advancement of crop growth up to harvest, the maximum being during 60 to 90 DAS regardless of crop establishment methods, residue and nutrient management treatments. The effect of crop establishment methods and residue management was found significant at all the crop growth periods except at 30 DAS. The dry matter accumulation in PB+R at 60 DAS (444.8 and 455.9 g/m.r.l.), 90 DAS (695.2

TABLE 1
Effect of crop establishment methods, residue and nutrient management on dry matter accumulation of maize

Treatments	Dry matter accumulation (g/m.r.l.)							
	30 DAS		60 DAS		90 DAS		At harvest	
	2022	2023	2022	2023	2022	2023	2022	2023
Crop establishment methods and residue management								
CT-R	184.0	188.1	400.1	406.3	623.4	633.1	725.6	721.2
CT+R	185.8	190.6	408.9	416.7	636.3	659.4	739.3	759.1
PB-R	189.1	194.6	434.5	444.3	679.7	689.1	787.5	798.7
PB+R	190.2	196.1	444.8	455.9	695.2	707.8	805.2	819.8
S. Em±	2.6	2.6	6.9	6.8	11.0	8.1	12.8	12.2
C. D. (P=0.05)	NS	NS	24.0	23.6	38.2	28.2	44.3	42.1
Nutrient management								
75% RDF	182.2	187.5	402.4	414.1	627.2	648.4	728.8	731.8
87% RDF	184.6	189.5	413.8	425.0	646.2	663.3	751.0	760.4
100% RDF	187.8	193.0	424.4	433.9	663.7	676.4	770.9	777.5
113% RDF	190.2	195.1	432.7	439.2	674.8	685.1	783.3	792.0
125% RDF	191.6	196.6	437.5	442.8	681.5	688.7	788.4	811.8
S. Em±	1.9	1.9	4.8	4.6	7.7	5.3	8.9	10.3
C. D. (P=0.05)	5.5	5.4	13.8	13.3	22.1	15.2	25.7	29.8

and 707.8 g/m.r.l.) and at harvest (805.5 and 819.8 g/m.r.l.) was significantly higher than other crop establishment methods except for PB-R during 2022 and 2023, respectively. The minimum dry matter accumulation was found in CT-R at all the growth periods which was statistically at par with CT+R in both years. Among nutrient management treatments, the maximum dry matter accumulation was found with 125% RDF at 30 DAS (191.6 and 196.6 g/m.r.l.), 60 DAS (437.5 and 442.8 g/m.r.l.), 90 DAS (681.5 and 688.7 g/m.r.l.) and at harvest (788.4 and 811.8 g/m.r.l.) during 2022 and 2023, respectively. The dry matter accumulation with 125% RDF was significantly higher than 87 and 75% RDF at all the crop growth periods in both years. The minimum dry matter accumulation was found with 75% RDF at all the growth periods in both years.

Stover yield (kg/ha)

The data on the stover yield of maize is given in Table 2. The data exhibited that the stover yield of maize was significantly higher under PB+R (8788 and 10423 kg/ha) as compared to CT+R and CT-R during 2022 and 2023, respectively. Whereas, the stover yield of CT+R and CT-R was statistically at par with each other in both years. The stover yield as influenced by different nutrient management treatments followed a similar pattern to biological yield in both years. Among different nutrient management treatments, the highest stover yield was obtained with 125% RDF (8554 and 9779 kg/ha) and the lowest with 75% RDF (7621 and 8701 kg/ha), achieving a significant increase of 12.2 and 12.4% during 2022 and 2023, respectively.

TABLE 2
Effect of crop establishment methods, residue and nutrient management on stover yield of maize

Treatments	Stover yield (kg/ha)	
	2022	2023
Crop establishment methods and residue management		
CT-R	7494	8276
CT+R	7795	8855
PB-R	8517	9716
PB+R	8788	10423
S. Em±	205	231
C. D. (P=0.05)	709	799
Nutrient management		
75% RDF	7621	8701
87% RDF	7938	9057
100% RDF	8210	9427
113% RDF	8420	9624
125% RDF	8554	9779
S. Em±	164	150
C. D. (P=0.05)	473	432

Protein content (%)

The crop establishment methods & residue management did not significantly influence the protein

content of maize in both years (Table 3). However, protein content in PB+R (11.6 and 11.7%) was numerically higher over other treatments in both years. The protein content was significantly affected by the nutrient management treatments and the highest protein content was found with 125% RDF which was statistically at par with 113 and 100% RDF in both years. The minimum protein content was observed with 75% RDF in both years (Table 3).

TABLE 3
Effect of crop establishment methods, residue and nutrient management on protein content and protein yield of maize

Treatments	Protein content (%)		Protein yield (kg/ha)	
	2022	2023	2022	2023
Crop establishment methods and residue management				
CT-R	10.9	11	476.0	506.6
CT+R	11.0	11.2	508.1	546.4
PB-R	11.3	11.3	560.8	597.5
PB+R	11.6	11.7	609.8	649.9
S. Em±	0.1	0.1	17.3	18.4
C. D. (P=0.05)	NS	NS	59.8	63.7
Nutrient management				
75% RDF	10.9	11.1	486.0	517.6
87% RDF	11.1	11.2	517.6	552.2
100% RDF	11.2	11.3	547.8	585.0
113% RDF	11.3	11.5	566.2	604.5
125% RDF	11.4	11.5	575.7	616.2
S. Em±	0.1	0.1	10.9	12.9
C. D. (P=0.05)	0.2	0.2	31.3	37.1

Protein yield (kg/ha)

It is clear from the data given in Table 3 that crop establishment methods, residue and nutrient management significantly affected the protein yield of maize in both years. The protein yield under PB+R (609.8 and 649.9 kg/ha) was significantly higher over other crop establishment methods and residue management except PB-R during 2022 and 2023, respectively. Among nutrient management treatments, the maximum protein yield was observed with 125% RDF (575.7 and 616.2 kg/ha) which was statistically indifferent with 113 and 100% RDF in both years.

Dry matter accumulation (g/mrl)

The data related to dry matter accumulation of wheat are shown in Table 4. It is clear from the table that regardless of crop establishment methods, residue and nutrient management treatments, dry matter accumulation increased continuously with the advancement of crop age up to harvest. Notably, the increase in dry matter accumulation was more pronounced between 60 to 90 DAS as compared to other crop growth periods in both years.

The effect of crop establishment methods and residue management treatments was found significant at all the crop growth periods except at 30 DAS in both years. The maximum dry matter accumulation was recorded under PB+R at 60 DAS (44.9 and 48.1

TABLE 4
Effect of crop establishment methods, residue and nutrient management on dry matter accumulation of wheat

Treatments	Dry matter accumulation (g/m.r.l.)									
	30 DAS		60 DAS		90 DAS		120 DAS		At harvest	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
Crop establishment methods and residue management										
CT-R	10.4	12.1	40.6	41.2	186.3	187.8	291.5	293.9	300.0	301.3
CT+R	10.6	12.4	41.5	44.0	190.8	201.4	299.0	316.1	307.1	324.9
PB-R	10.8	12.5	43.0	45.2	197.4	207.5	308.9	321.9	318.2	330.6
PB+R	11.0	12.6	44.9	48.1	207.0	222.7	324.5	346.6	333.5	355.4
S. Em±	0.1	0.1	0.7	0.8	3.2	3.9	5.9	6.1	5.5	6.5
C. D. (P=0.05)	NS	NS	2.4	2.7	11.1	13.4	20.4	21.2	18.9	22.4
Nutrient management										
75% RDF	10.3	12.1	40.7	42.6	187.2	197.1	293.2	308.1	301.9	316.3
87% RDF	10.5	12.3	41.6	43.9	191.9	201.6	301.7	314.5	310.5	323.2
100% RDF	10.7	12.4	42.7	45.1	196.5	205.7	308.4	322.7	317.1	329.7
113% RDF	10.9	12.6	43.4	45.6	199.7	209.4	312.0	324.7	320.7	334.6
125% RDF	11.0	12.6	43.8	46.0	201.3	210.6	314.6	328.8	323.2	336.6
S. Em±	0.1	0.1	0.5	0.3	2.5	1.6	3.7	2.3	3.9	2.5
C. D. (P=0.05)	0.3	0.2	1.6	0.9	7.2	4.5	10.8	6.6	11.3	7.3

g/mrl), 90 DAS (207.0 and 222.7 g/mrl), 120 DAS (324.5 and 346.6 g/mrl) and harvest (333.5 and 355.4 g/mrl) during 2022-23 and 2023-24, respectively. It was statistically at par with PB-R during 2022-23 and significantly higher over the rest of the treatments during 2023-24, respectively. The dry matter accumulation in CT+R at 60, 90, 120 DAS and harvest was statistically at par with CT-R during 2022-23 and significantly higher over CT-R during 2023-24.

Straw yield (kg/ha)

The data regarding straw yield given in Table 5 indicated that the straw yield was significantly affected by crop establishment methods, residue and nutrient management in both years. Among crop establishment methods and residue management, the maximum straw yield was found with PB+R (6852 and 7007 kg/ha) during 2022-23 and 2023-24, respectively which was significantly higher than CT+R (5820 and 6203 kg/ha) and CT-R (5553 and 5647 kg/ha) during 2022-23 and significantly higher than all the other treatments during 2023-24. The straw yield under PB-R was statistically at par with CT+R in both years. Furthermore, the straw yield of CT+R was statistically at par with CT-R during 2022-23 and significantly higher during 2023-24. The straw yield under different nutrient management treatments varied from 5764 to 6455 kg/ha during 2022-23 and from 5998 to 6544 kg/ha during 2023-24. It was recorded maximum with 125% RDF (6455 and 6544 kg/ha) which significantly outyielded all other treatments except 100 and 113% RDF during 2022-23 and 2023-24, respectively. The grain yield with 113% RDF was significantly higher over 75 and 87% RDF in both years, while 100% RDF significantly out-yielded 75% RDF in both years.

Protein content (%)

The crop establishment methods & residue treatments did not significantly influence the protein content in both years (Table 6). However, the protein content in PB+R (11.4 and 11.6%) was numerically the highest among different crop establishment methods and residue management treatments in both years. Among nutrient management, the maximum protein content was recorded with 125% RDF which was statistically at par with 113 and 100% RDF in both years (Table 6).

Protein yield (kg/ha)

It is clear from the data given in table 6 that crop establishment methods, residue and nutrient management had a significant effect on the protein yield in both years. The protein yield under PB+R (616.3 and 647.0 kg/ha) was significantly higher over PB-R (579.4 and 590.1 kg/ha), CT+R (542.1 and 573.2 kg/ha) and CT-R (513.7 and 517.2 kg/ha) during 2022-23 and 2023-24, respectively. Among nutrient management, the protein yield was found maximum with 125% RDF which was statistically at par with 113% RDF in both years.

TABLE 5
Effect of crop establishment methods, residue and nutrient management on yield of wheat

Treatments	Stover yield (kg/ha)	
	2022-23	2023-24
Crop establishment methods and residue management		
CT-R	5553	5647
CT+R	5820	6203
PB-R	6367	6436
PB+R	6852	7007
S. Em±	168	155
C. D. (P=0.05)	581	536
Nutrient management		
75% RDF	5764	5998
87% RDF	5987	6208
100% RDF	6191	6385
113% RDF	6343	6483
125% RDF	6455	6544
S. Em±	109	88
C. D. (P=0.05)	314	255

TABLE 6
Effect of crop establishment methods, residue and nutrient management on protein content and protein yield of wheat

Treatments	Protein content (%)		Protein yield (kg/ha)	
	2022-23	2023-24	2022-23	2023-24
Crop establishment methods and residue management				
CT-R	11.2	11.2	513.7	517.2
CT+R	11.2	11.4	542.1	573.2
PB-R	11.4	11.5	579.4	590.1
PB+R	11.4	11.6	616.3	647.0
S. Em±	0.07	0.09	11.2	13.2
C. D. (P=0.05)	NS	NS	38.8	45.6
Nutrient management				
75% RDF	11.1	11.1	520.9	533.0
87% RDF	11.2	11.3	544.4	562.0
100% RDF	11.3	11.4	568.3	588.9
113% RDF	11.4	11.5	584.8	606.4
125% RDF	11.5	11.6	596.0	618.9
S. Em±	0.06	0.07	9.0	9.7
C. D. (P=0.05)	0.2	0.2	26.0	28.0

CONCLUSION

Among crop establishment methods and residue management, PB+R recorded significantly higher dry matter accumulation and stover/straw of maize and wheat in comparison to conventional crop establishment method with or without residue retention in both years. The protein yield was recorded higher in PB+R than conventional crop establishment method with or without residue retention in both years. The dry matter accumulation and stover/straw of maize of both maize and wheat were recorded significantly higher with 125% RDF than 87 and 75% RDF in both years.

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