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Planting density and nitrogen management effects on productivity, quality and water-use-efficiency of Indian mustard under conservation agriculture based pearl millet – mustard system

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Abstract

A field experiment was carried out during 2016 at the research farm of IARI, New Delhi to study the effect of planting density and nitrogen management protocols on productivity, quality and water-use-efficiency of Indian mustard under conservation agriculture based pearl millet – mustard system. The experiment comprised of 3 planting density; normal distance sowing (P_1), high density sowing *fb* alternate row harvesting for fodder at 35 DAS (P_2) and high density sowing *fb* alternate row harvesting for mulch at 35 DAS (P_3) in main plots and five treatments of nitrogen management [control (N_0), 60 kg N ha⁻¹ as basal (N_1), 30 kg N ha⁻¹ as basal + 30 kg N ha⁻¹ as side dressing (N_2), 75 kg N ha⁻¹ as basal (N_3) and 37.5 kg N ha⁻¹ as basal + 37.5 kg N ha⁻¹ as side dressing (N_4)]. Maximum production efficiency (13.54 kg ha⁻¹day⁻¹), net returns (42213 ₹ ha⁻¹) and monetary efficiency (338 ₹ ha⁻¹day⁻¹) were recorded under P_2 . Whereas, seed yield (1681 kg ha⁻¹) was founded maximum in P_3 treatment. The highest protein yield (326 kg ha⁻¹) and water-use-efficiency (8.26 kg ha⁻¹mm⁻¹) were recorded from treatment P_3 and consumptive water use (210.8 mm) and rate of moisture use (1.69 mm day⁻¹) were realized from treatment P_2 . Among N-management treatments, N_4 resulted in the highest seed yield (1893 kg ha⁻¹), production efficiency (15.51 kg ha⁻¹day⁻¹), net returns (52371 ₹ ha⁻¹) and monetary efficiency (419 ₹ ha⁻¹day⁻¹). The same treatment also recorded highest grain protein content (19.70%), protein yield (373 kg ha⁻¹), oil content (38.0%) oil yield (720 kg ha⁻¹), consumptive use of water (211.7 mm) and water-use-efficiency (8.95 kg ha⁻¹mm⁻¹).

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Introduction

Among major cropping systems of water stressed ecologies and marginal lands, pearl millet [*Pennisetum glaucum* (L.) R. Br. emend Stuntz] – Indian mustard [*Brassica juncea* (L.) Czern and Coss] production system has a significant role in the economy and livelihood. In India, the cropping system covers around 937 thousand hectare area and contributes about 3.5% of Indian food basket (Bamboriya 2016). In semi-arid tract of India, particularly East of the Aravalli series in Rajasthan, adjoining parts of Madhya Pradesh and Gujarat, parts of Haryana and Uttar Pradesh, where mono-cropping of either pearl millet or mustard (mainly pearl millet) was a conventional cropping system, development in irrigation infrastructure and water smart irrigation methods has made it possible to cultivate the crops in rotation with 200% cropping intensity. Low input and labour requirement and relatively better market prices of mustard are some of the reasons of preference and enhancement in the area under pearl millet – mustard rotation. Now, mustard is being cultivated in an area of 6.1 million hectare with total production of 9.2 million tonnes at an average productivity of 1,511 kg ha⁻¹ (Anonymous 2021).

Conservation agriculture (CA), which consists of no tillage, retaining surface residue cover and adoption of sustainable rotations, helps in achieving twin objectives of reduced production cost and lower land degradation (Castro et al. 1991; Choudhary et al. 2019) and improves soil physical, chemical and biological properties (Bana et al. 2020). Moreover, mulch cover and less soil disturbance in CA systems enhances soil

moisture and nutrients status in the rhizosphere, specifically under semi-arid dryland ecologies (Bamboriya et al. 2017a). Likewise, organic mulch application owing to its poor heat conduction effectively moderates soil temperature, maintains soil profile moisture and enhances nutrient status of the soil (Choudhary et al. 2017; Bana et al. 2018).

The wide spread use of crop residues for livestock and low biomass productivity in rainfed systems, farmers sometimes face a scarcity of crop residues. This leads to trade-off for crop residues between CA systems and livestock feeding under crop-livestock based mixed farming systems. Thus residue availability becomes the foremost constraint for promotion of CA under rainfed ecologies (Bamboriya et al. 2017b). Further, lack of knowledge and information on nutrient management protocols under CA systems is a challenge about the potential of CA to agriculture leaders, extension agents and farmers. Since the whole range of practices in CA, including planting and harvesting, water and nutrient management etc. need to be evolved, evaluated and matched in the context of new systems (Saharawat et al. 2007). Therefore, keeping these in view, the present investigation was carried out to study the effect of planting density and nitrogen management protocols on productivity, quality and water-use efficiency in conservation agriculture-based mustard under pearl millet – mustard rotation.

Materials and Methods

The experiment was conducted at Indian Agricultural Research Institute, New Delhi, situated at 28° 4'N latitude, 77° 12'E longitude and at 228.6 m above mean sea level

in 2016. The experimental soil was sandy loam with alkaline pH (7.5) and poor in available N (142 kg ha^{-1}), medium in available P (15.6 kg ha^{-1}) and K (205 kg ha^{-1}). The total rainfall received during crop growing period (*rabi*) was 11.38 mm. The field experiment comprised of three main plot treatments, planting density *viz.*, normal distance sowing (P_1), high density sowing *fb* alternate row harvesting for fodder at 35 DAS (P_2), high density sowing *fb* alternate row harvesting for mulch at 35 DAS (P_3) and five sub-plot treatments nitrogen management *viz.*, control (No), 60 kg N ha^{-1} as basal (N_1), 30 kg N ha^{-1} as basal + 30 kg N ha^{-1} as side dressing (N_2), 75 kg N ha^{-1} as basal (N_3) $37.5 \text{ kg N ha}^{-1}$ as basal + $37.5 \text{ kg N ha}^{-1}$ as side dressing (N_4). Mustard variety "Pusa mustard - 26" was sown using happy seeder on 24 October, 2016 following a seed rate of @ $4 \text{ kg seed ha}^{-1}$ in P_1 plot and @ $8 \text{ kg seed ha}^{-1}$ in P_2 and P_3 treatments. Plant population was maintained as $1,50,000 \text{ plants ha}^{-1}$ ($45 \text{ cm} \times 15 \text{ cm}$) in P_1 and $3,00,000 \text{ plants ha}^{-1}$ (22.5×15) in P_2 and P_3 . Alternate rows from P_2 and P_3 plots were harvested for fodder and for mulch at 35 DAS, respectively. Urea was drilled in bands 5 cm below the surface during mustard sowing. Side-dressing of urea was done at 30 DAS as per treatments.

The grain-equivalent yield of green fodder and grain-equivalent yield of stover are added to grain yield to work out system yield. The system yield was divided by duration of crop to calculate the production efficiency. The protein content (%) was estimated by multiplying nitrogen content of grain by standard factor 6.25. Estimation of quality parameters was carried out as per standard

methods, as suggested by Rana *et al.*, 2014. Consumptive use was calculated as: Consumptive use (mm) = $\Sigma(b_j - e_j)$ + effective rainfall where, b_j = total profile moisture content at the beginning of the j^{th} interval; e_j = total profile moisture at the end of the j^{th} interval. Water-use efficiency was worked out by dividing grain yield with seasonal crop consumptive use of water. Rate of moisture use was worked out by dividing consumptive use of water by crop duration. Monetary efficiency was derived by dividing net returns with total duration of the crop.

Result and Discussion

Planting density did not affect mustard seed yield significantly (Table 1). The highest seed yield ($1,681 \text{ kg ha}^{-1}$) however, was recorded under P_3 followed by P_1 ($1,624 \text{ kg ha}^{-1}$) and P_2 ($1,560 \text{ kg ha}^{-1}$). Under P_3 the per cent improvement in seed yield was 3.5% and 7.7% over P_1 and P_2 , respectively. The result shows that P_2 treatment resulted in higher production efficiency ($13.54 \text{ kg ha}^{-1} \text{ day}^{-1}$) as compared to P_3 ($13.45 \text{ kg ha}^{-1} \text{ day}^{-1}$) and P_1 ($12.99 \text{ kg ha}^{-1} \text{ day}^{-1}$). Production efficiency enhanced significantly with high P_2 owing to higher grain equivalent yield of green forage obtained by alternate row harvesting. Though the highest protein content and protein yield were (19.35% and 326 kg ha^{-1}) found under P_3 . The P_2 sowing resulted in significantly higher consumptive use (CU) of water (210.8 mm) and P_3 sowing resulted in significantly higher water-use efficiency in mustard ($8.26 \text{ kg ha}^{-1} \text{ mm}^{-1}$). Consumptive use of water increases in exact proportion to the dry weight production. Up to alternate row harvesting stage, CU was more at high density plots attributed to enhanced vegetative growth per

unit area. The P₂ treatment was found more profitable because of higher net returns and monetary efficiency. The increased profitability under this treatments may be ascribed to the comparatively lower cost

involved under this treatment. The different treatments of planting density unsuccessful to produce any significant variation on grain quality parameters in mustard (Table 2).

Table 1. Effect of planting density and nitrogen management on system of yield, production efficiency, water-use-efficiency and economics of mustard

Treatment	Seed yield (kg/ha)	Production efficiency (kg/ha-day)	Consumptive use of water (mm)	Water-use-efficiency (kg/ha-mm)	Rate of moisture use (mm/day)	Net returns(₹/ha)	Monetary efficiency (₹/ha-day)
Planting density							
P ₁	1624	12.99	205.6	7.88	1.64	41,594	333
P ₂	1560	13.54	210.8	7.37	1.69	42,213	338
P ₃	1681	13.45	203.0	8.26	1.62	42,122	337
CD	NS	NS	210.8	7.37	1.69	NS	NS
(P=0.05)							
Nitrogen management							
N ₀	1079	8.91	198.7	5.44	1.59	20,954	168
N ₁	1575	12.98	204.7	7.71	1.64	40,273	322
N ₂	1776	14.53	208.0	8.54	1.66	47,623	381
N ₃	1786	14.69	209.3	8.53	1.67	48,661	389
N ₄	1893	15.51	211.7	8.95	1.69	52,371	419
CD	198.6	1.49	--	--	--	7,332	58.6
(P=0.05)							

Nitrogen-management practices also significantly influenced seed yield and production efficiency (Table1). Mustard crop fertilized with N₄treatment produced highest seed yield (1,893 kg ha⁻¹) and production efficiency (15.51 kg ha⁻¹ day⁻¹) which were closely followed by N₃ and N₂. It remained significantly superior to N₁ and N₀treatments. In residue-based zero-till farming systems, slower soil N mineralization and greater immobilization, especially during initial periods of adoption of CA, hinders the crop production. So, application of slightly higher than recommended dose of N under CA-based system compensates the lesser N availability

due to immobilization of N and thus enhance yield and production efficiency (Bamboriya et al. 2017a). Availability of nitrogen through mineralization of N at reproductive stage might be responsible for the similar performance of basal application than split application of N. Bana and Shivay 2012; Bana et al, 2013; Bana et al. 2015 also reported enhanced crop growth and productivity due to efficient nitrogen management. The highest consumptive use of water (211.7 mm) was observed under N₄ followed N₃ (209.3 mm), N₂ (208.0 mm), N₁ (204.7 mm) and N₀ (198.7 mm).The N₄ treatment recorded significantly higher rate of moisture use (1.69 mm⁻¹ day⁻¹)

followed by N_3 (1.67 mmday^{-1}), N_2 (1.66 mmday^{-1}), N_1 (1.64 mmday^{-1}) and N_0 (1.59 mmday^{-1}). Treatments N_3 , N_2 , N_1 and N_0 decreased the rate of moisture use by 1.20%, 1.80%, 3.0% and 6.30%, respectively, compared to N_4 . It may be ascribed due to enhanced vegetative growth and an extensive

proliferation and deeper root-system due to better nutrition that enabled the plant to utilize more moisture from deeper horizons of soil profile and extract more nutrients from soil profile. The findings are in close proximity to that of Tatarwal & Rana 2006; Kumar et al. 2015 and Bamboriya et al. 2017.

Table 2. Effect of different treatments on grain quality of mustard

Treatment	Grain quality			
	Oil content (%)	Oil yield (kg/ha)	Protein content (%)	Protein yield (kg/ha)
Planting density				
P_1	39.6	642	19.20	313
P_2	39.7	617	18.73	295
P_3	39.8	667	19.35	326
CD ($P=0.05$)	NS	NS	NS	NS
Nitrogen management				
N_0	40.5	437	17.84	192
N_1	40.2	633	19.17	302
N_2	40.3	715	19.45	345
N_3	39.5	706	19.30	345
N_4	38.0	720	19.70	373
CD ($P=0.05$)	0.42	80.31	1.02	39.0

Water-use efficiency was also increased with increasing N levels. It might be owing to the fact that increase in yield was of higher magnitude than the corresponding increase in CU of water, eventually resulted in considerable increase in WUE owing to N levels (Bana et al. 2016; Bana et al. 2018). Application of N_4 recorded significantly higher water-use efficiency ($8.95 \text{ kg ha}^{-1} \text{ mm}^{-1}$) followed by N_3 ($8.54 \text{ kg ha}^{-1} \text{ mm}^{-1}$), N_2 and N_1 and N_0 . With increasing doses of N up to the highest level, the net return was increased over the control. Application of N_4 treatment to the mustard crop realized significantly higher net return ($52,371 \text{ ₹ ha}^{-1}$) and monetary efficiency ($419 \text{ ₹ ha}^{-1} \text{ day}^{-1}$), being at par with N_3 and N_2 . Mustard grain oil content and oil

yield were highest in N_0 and N_4 treatments, respectively (Table 2). Appreciable increase in protein per cent in mustard grain was observed with an increase in subsequent level of nitrogen. The N_4 treatment resulted in the highest grain protein content (19.70%) as well as protein yield (373 kg ha^{-1}). Nitrogen is an important constituent of protein, which always shows a marked promoting influence on protein synthesis by way of promoting synthesis of amino acids, which are constituent building blocks of protein (Bana & Gautum 2009; Jhadav et al. 2011; Bana et al. 2012).

In a short period study, it can be concluded that high density sowing *fb* alternate row harvesting for fodder at 35 DAS

is a suitable practice to achieve more forage yield and profits. Hence, it can be a potential panacea to the problem of forage shortage under CA. For getting higher yield with more return under conservation agriculture especially during initial period of CA adoption, mustard crop should be fertilized in split application ($37.5 \text{ kg N ha}^{-1}$ as basal + $37.5 \text{ kg N ha}^{-1}$ as side dressing).

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