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Double Cropping Systems for Sustainability and Livelihood Security in Rainfed Alfisols

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ABSTRACT: In dryland agriculture, traditional mono-cropping systems face challenges due to limited water availability and erratic rainfall patterns, leading to moisture stress and soil degradation. This study investigates the potential of double cropping systems with pulses and oilseeds to enhance productivity and sustainability in dryland regions. The experiment was conducted at the Gungal Research Farm during 2022-23 to evaluate six pulse-oilseed cropping systems with and without rainwater management against existing intercropping system of sorghum+ pigeonpea (2:1). Cowpea emerged as a promising crop, exhibiting higher yield (1415 kg/ha) compared to other pulses. Double crop of sesame and cowpea showed promising results, offering substantial yields and total crop yield per unit area (1655 kg/ha). Rainwater management significantly influenced crop performance. Apart from the yield, the price of both cowpea and sesame resulted in higher crop equivalent yield (1688 and 1597 kg/ha) compared to other cropping systems with and without rainwater management. Overall, the study emphasizes that cowpea- sesame system with rainwater management is the best system that resulted in higher green gram equivalent yield (1655 kg/ha).

Keywords: Double crop, pulses-oilseed system, rainwater management

Introduction

The drylands are generally mono-cropped resulting in a lower cropping intensity. Farmers raise crops either in the monsoon season and leave the fields fallow in the post-monsoon season in Alfisols or conserve rainwater in the monsoon season and take a crop in the post-monsoon season in Vertisols. This is mainly because of the use of long-duration crop varieties. The ever-increasing requirements and progressively shrinking per capita availability of agricultural land warrant temporal and spatial intensification of cropping. The selection of an efficient cropping system for a region is influenced by several factors. Besides climate, soils and socio-economic factors, the important ones are the selection of suitable crops, cultivars, duration and crop genotypes. Dryland areas, characterized by limited water availability and erratic rainfall patterns, pose significant challenges to traditional mono-cropping systems due to moisture stress and soil degradation. However, by employing double cropping systems with pulses and oilseeds, farmers can harness the benefits of crop diversification, improved nutrient cycling and enhanced water-use efficiency. In drylands, an efficient double cropping system can be developed if the long-duration crop is replaced by a short-duration high-yielding crop variety. In any climatic condition, for a successful double cropping, early planting of the *kharif* crop and its harvest as early as possible helps in the quick establishment of the *rabi* crop. Double cropping systems, particularly those integrating pulses and oilseeds, represent a sustainable agricultural strategy aimed at maximizing land productivity, enhancing soil fertility, and ensuring food and economic security in dryland regions (Zentner *et al.,* 2001).

Pulses, which include leguminous crops such as cowpea, black gram and green gram, play a crucial role in double cropping systems due to their ability to fix atmospheric nitrogen. This not only reduces the dependence on external inputs of synthetic fertilizers but also enriches the soil with organic matter, thereby promoting soil health and fertility (Nielsen and Jensen, 2005; Kell, 2011; Kumar *et al.,* 2023). Additionally, pulses serve as valuable protein sources in human diets, contributing to food security and nutrition in dryland regions. On the other hand, oilseed crops such as safflower and sesame, complement pulses in double cropping systems by diversifying crop rotations and enhancing farm income through the production of high-value oils.

The implementation of double cropping systems with pulses and oilseeds requires a comprehensive understanding of agronomic practices, cropping calendars and environmental conditions specific to each region. Scientific research plays a pivotal role in guiding the development and optimization of these systems, addressing challenges such as crop selection, pest and disease management and water conservation strategies tailored to dryland environments (Wang *et al.,* 2003). A proper rainwater management improves the success of second crop in rainfed areas. The water during the rainy season can be harvested and used for raising the second crop in the *rabi* season. Hence an attempt was made to identify a climate-adaptive double cropping system with pulses and oilseed for Alfisols.

Materials and Methods

The study was carried out at the Gungal Research Farm of ICAR-Central Research Institute for Dryland Agriculture (17°05' N, 78°39'E) during 2022-2023. Six different pulse- oilseed cropping systems were studied with and without rainwater management. The pulses were sown during the *kharif* and the oilseed crops were sown after the harvest of the pulse crop (October). The crops under rainwater management were given 2 supplementary irrigations (3 mm) from the water harvested during *kharif* season. The soil of the experimental field was sandy loamy with a pH of 6.04 and EC 0.12 dS/m, low in available nitrogen (215.48 kg/ha) medium in available phosphorus (26.73 kg/ha) and available potassium (218.34 kg/ha). The experiment was laid out in a Randomized block design and replicated thrice. The fertilizers were applied as per the recommendation. The treatments are presented in Table 1. The variety seed rate, spacing, fertilizers, sowing time and harvesting time are mentioned in Table 2.

Table 1: Details of treatments/cropping systems

Abbreviation	Treatment
S+PP	Sorghum+ pigeonpea (2:1)
BG-SS+	Blackgram followed by sesamum with rainwater management
BG-SS-	Blackgram followed by sesamum without rainwater management
BG-SF+	Blackgram followed by safflower with rainwater management
BG-SF-	Blackgram followed by safflower without rainwater management
CP-SS+	Cowpea followed by sesamum with rainwater management
CP-SS-	Cowpea followed by sesamum without rainwater management
CP-SF+	Cowpea followed by safflower with rainwater management
CP-SF-	Cowpea followed by safflower without rainwater management
GG-SS+	Greengram followed by sesamum with rainwater management
GG-SS-	Greengram followed by sesamum without rainwater management
GG-SF+	Greengram followed by safflower with rainwater management
GG-SF-	Greengram followed by safflower without rainwater management

Table 2: Management practices of crops under study

Crop	Variety	Seed rate/ Kg/ha	Spacing (cm)	Fertilizer (NPK) (kg/ha)	Sowing	Harvesting
Green gram	WGG37	10-15	30×10	20:50:0	27 June	13 September
Cowpea	TPTC29	20-25	40×20	20:40:0	27 June	19 September
Black gram	JS9305	20-25	45×20	20:50:0	27 June	19 September
Sorghum	CSV23	12-15	45×10	80:40:0	27 June	8 November
Pigeon pea	PRG176	10-12	90×20	80:40:0	27 June	10 January
Safflower	ISF-64	12-15	45×20	40:25:20	8 October	13 February
Sesame	Shweta til	5-7	45×20	40:20:20	8 October	9 January

As different crops were studied, after the harvest of the crops, greengram equivalent yield (GGEY) of all other crops was calculated using the following formula:

$$\text{GGEY (kg/ha)} = \frac{\text{Yield of crop X price of crop}}{\text{Price of green gram}}$$

Results and Discussion

Growth attributes

Since the treatments were different crops, the plant heights were not comparable. However, in terms of rainwater management strategies, both oilseed crops had taller plants with two supplementary irrigations compared to no irrigation. Cowpea-sesamum with rainwater management had 19% increase in plant height compared to no rainwater management (Table 3). In greengram-sesamum with rainwater management, sesamum recorded 86.5 cm of plant height compared to 70.6 cm without rainwater management. Higher plant height of sesamum under different intercropping treatments as compared to sole sesamum was also reported by Krishna and Reddy (2005). Cowpea rapidly extracts soil water for growth and effectively competes with other crops and weeds (Hattlendorf *et al*., 1988; Lightfoot *et al*., 1987). The better ground coverage and addition of nitrogen by cowpea might have resulted in better growth of second crop (sesamum). The dense canopy of cowpea also resulted in higher LAI. Cowpea exhibited the highest LAI (1.86) followed by green gram (1.79). The lowest was observed in sorghum (1.43) and pigeonpea (1.76) (Table 3). Without rainwater management for the oilseed crop (second crop), the highest LAI was recorded for sesamum (1.28) in black gram-sesamum system which was on par with sesamum (1.25) in cowpea-sesamum system. LAI was found higher in cowpea-safflower (1.72), followed by blackgram-safflower (1.65) with rainwater management.

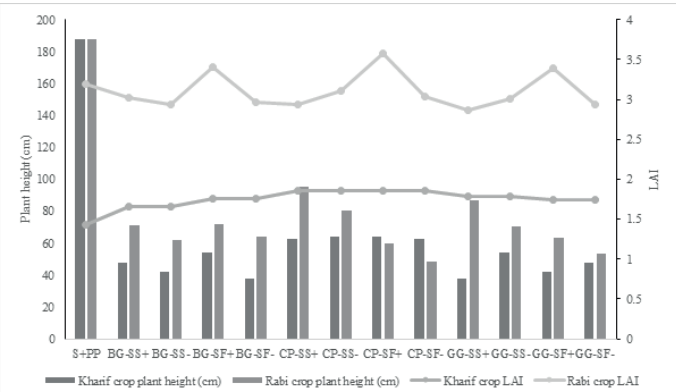

Fig. 1: Plant height and LAI of different cropping systems

The LAI of safflower in blackgram-safflower was on par with the pigeonpea LAI (1.76) (Fig 1). The improved LAI shows that safflower's deep taproot system effectively utilized the soil moisture from deeper layers making it to perform better in water limited condition. Moreover, safflower exhibits drought tolerance traits, such as reduced transpiration rate and increased water use efficiency, which help it, thrive under water-deficient conditions. Scientific evidence supports safflower's suitability for dryland agriculture; for example, a study by Shavrukov *et al.* (2017) identified key drought-responsive genes in safflower, elucidating mechanisms underlying its drought tolerance. Additionally, research by Jukanti *et al.* (2017) demonstrated safflower's potential for enhancing resilience in dryland cropping systems through its superior water use efficiency and adaptability to harsh environments.

Yield attributes and yield

Among the pulses**,** the highest number of pods per plant was observed in cowpea (16) followed by black gram and greengram. During the *rabi* season, among the oilseeds, the highest number of pods per plant were observed in safflower (28) with rainwater management in cowpea-safflower system (Fig 2). Without rainwater management, the highest number of pods was observed in safflower (20) in cowpea-safflower, followed by both cowpea-sesamum and green gram-sesamum. The trend remained the same for the number of seeds per pod. Highest number of seeds per pod was observed in cowpea (16) followed by blackgram. Among the oilseeds crops, under rainwater management, sesamum recorded higher seeds per pod (77) in cowpea-sesamum system followed by sesamum (76) in greengram-sesamum system. Without rainwater management, the highest number of seeds per pods was observed in sesamum (68) in cowpea-sesamum.

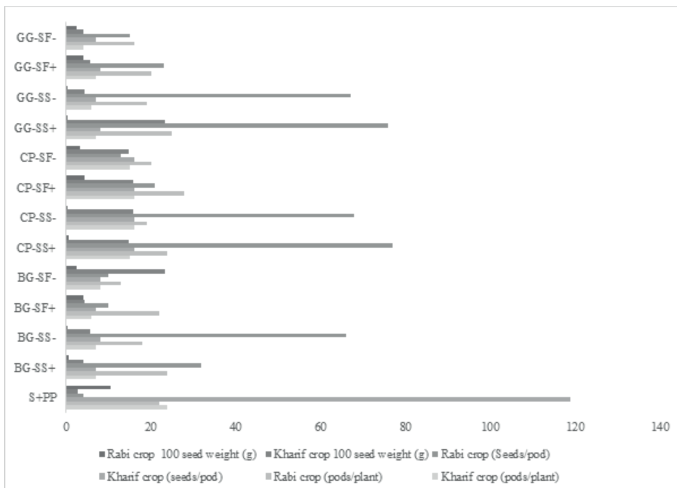

Fig. 2: Yield attributes of various double cropping systems

The first crop of pulses and the rainwater management influenced the yield of oilseed crops in the study. Among the pulses, the highest yield was recorded in cowpea (1415 kg/ha) followed by blackgram (974 kg/ha). Use of rainwater for 2 supplementary irrigations improved the yield of safflower (681 kg/ha) in cowpea-safflower system compared to safflower yield 513 kg/ha in cowpea-safflower system without irrigation. The lowest yield was recorded in sesame (273 kg/ha) in greengram-sesamum system (Fig 3). Without rainwater management, highest yield was observed in safflower (517 kg/ha) in black gram-safflower system. The trend was same for the stover yield (Fig 3). The sorghum yield in the sorghum pigeonpea system was 1051 kg/ha and the pigeonpea yield was 890 kg/ha. The existing and adapted system sorghum + pigeon pea (2:1) resulted in less crop yield than its potential and system yield mainly because of the late sowing of sorghum and moisture stress in the later stage. The optimum time for sowing sorghum is last week of May to first fortnight of June. The onset monsoon is delayed in this region from the past few years resulting in delay the sowing of the crop to July with poor plant population and heavily infested by fall armyworm. The pigeonpea performed better in the early stage, however, the moisture stress in the later stage resulted in poor pod filling and lower yield.

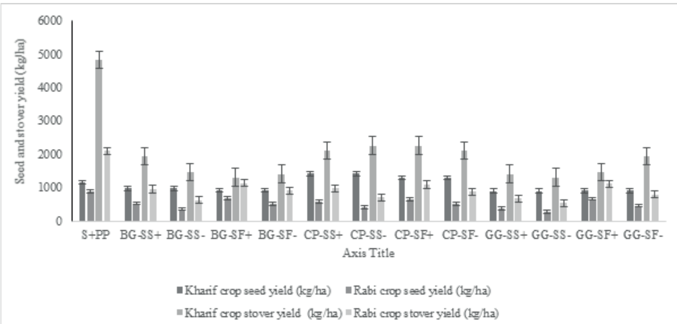

Fig 3: Seed yield and stover yield of various double cropping systems

The highest greengram equivalent yield (GGEY) was recorded for cowpea- sesamum system (1655 kg/ha) with rainwater management followed by cowpea-safflower system with rainwater management (1407 kg/ha). The sorghum + pigeonpea (2:1) intercropping system recorded a GGEY of 1200 kg/ha (Fig 4). Similar to safflower, sesame can also tolerate drought due to its extensive root system, although susceptible to drought during germination and seedling stages (Bahrami *et al*., 2012) and also commands a higher market price due to its superior oil quality. This resulted in higher GGEY of sesamum. The result also shows that cowpea-based system resulted in better yield. The ability of cowpea to fix atmospheric nitrogen might have enriched the soil nitrogen, promoting increased nutrient availability for subsequent crops. Additionally, cowpea's deep root system might have enhanced soil structure and moisture retention, facilitating better root penetration and nutrient uptake by subsequent crops. Several studies corroborate these benefits; for instance, a study by Egamberdieva *et al.* (2017) highlighted the positive impact of cowpea intercropping on soil fertility and subsequent crop yields. Moreover, cowpea's ability to suppress weeds and its role in breaking pest and disease cycles further contribute to improved crop productivity in following seasons (Singh *et al.,* 2019).

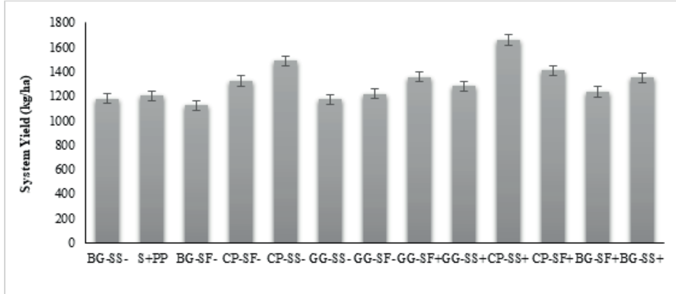

Fig 4: GGEY in various double cropping systems

Conclusion

This study demonstrates the potential of double cropping systems with pulses and oilseeds to address the challenges of limited water availability and erratic rainfall patterns in dryland agriculture. The results have shown cowpea emerging as a promising crop due to its higher growth and yield compared to other pulses. The use of rainwater management significantly influenced crop performance with notable improvements observed in plant height and yield attributes when supplementary irrigation was provided. Cowpea-sesame and cowpea-safflower double cropping systems, especially with rainwater management, exhibited promising results in terms of productivity and sustainability, offering substantial yields and total crop yield per unit area. Furthermore, the study highlights the importance of crop selection, agronomic practices and environmental management in optimizing double cropping systems for dryland regions. The findings underscore the resilience-enhancing potential of diversified cropping systems, contributing to improved livelihoods, soil fertility and food security in dryland agricultural landscapes. Further research and extension efforts are warranted to facilitate the adoption of these climate-adaptive cropping systems and promote their widespread implementation in dryland agriculture.

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