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Comparative evaluation of herbicide application through drone and power sprayer in soybean+pigeonpea intercropping system

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Abstract
A field experiment carried out at Experimental Farm, Krishi Vigyan Kendra (Selsura) Wardha, Maharashtra, India during *kharif 2024-25* entitled "Comparative evaluation of herbicides application through Drone and Power sprayer in soybean + pigeonpea intercropping system". The experiment comprising with eight treatments was laid out in randomized block design with three replications. Among the herbicidal treatments, application of Post emergence herbicidal combination of Imazethapyr + Imazamox @ 0.070 kg a.i./ha at 15 DAS through Power sprayer recorded highest soybean yield, pigeonpea yield, soybean equivalent yield, GMR, NMR and B:C ratio followed by Imazethapyr + Imazamox POE 0.070 kg a.i./ha at 15 DAS through Drone.

Keywords: Soybean+ Pigeon pea, Power sprayer, Drone, Imazethapyr, Imazamox

Introduction
Soybean a leguminous crop which belongs to family leguminoceae with sub family papillionaceae. It is originated in China. It is a *kharif* season growing crop and it is basically a pulse crop but in India mostly grown as oilseed crop. It is a world's first ranking crop as a source of vegetable oil. Soybean is a miracle golden bean of 20th century. Recently, it has become an important oilseed crop of India. Being rich source of protein (40-42%), rich in lysine (5%) and vegetable oil (20%) 85% of unsaturated fatty acids, 25-30% carbohydrates and almost no starch (useful to diabetic patients), 4-5% minerals, anti-oxidants *viz*. ascorbic acid and beta carotene and about 0.3% iso-flavones. That's why soybean is also called as Wonder crop, Miracle crop, Yellow jewel, and Golden bean.

India, despite being the fifth-largest producer of soybean, presents a different picture. In 2024-25, soybean was cultivated on around 12.8 million hectares, mainly during the Kharif season. Total production is estimated at 13.5 million tonnes, but the average yield remains relatively low, between 1.05 to 1.15 tonnes per hectare, far below the global average. The main soybean-growing states include Madhya Pradesh (which alone accounts for around 45% of India's production), followed by Maharashtra, Rajasthan, Telangana, Karnataka, and Chhattisgarh.

Pigeonpea one of the most important leguminous crops grown in tropical and subtropical regions of the world. It is commonly referred to as *Arhar* or *Tur* in India. This crop is valued not only for its protein-rich seeds, which form a staple part of diets in many countries. According to recent estimates, the global pigeonpea production stands at around 5 million tonnes annually, and India alone accounts for nearly 4.2 million tonnes of this, grown across approximately 4.5 to 5 million hectares of land. This highlights the crop's immense significance in India's agrarian economy, especially in rainfed and semi-arid regions.

Weed suppression, the reduction of weed growth by crop interference, has been referred as one determinant of yield advantage of intercropping. The first 20-40 days period after sowing of soybean is considered to be critical with respect to weed crop competition. Weed competition during this period may lead to 40-70% reduction in the seed yield of soybean depending upon the weed species present.

Weeds are known to cause 40-64% reduction in pigeonpea yield. The critical period of crop weed competition for pigeonpea is 4-8 weeks. Among various constraints in crop production weed control is important one but generally neglected by many farmers. The crop yield loss is 20 to 77 per cent due to weeds (Kurchania *et al*. 2001) [10]. Inter cropping suppress the growth of weeds up to 25% (Sobney *et al*. 1989) [17]. It is very essential to find out alternative to manual labour for weed control, which has more weed control efficiency. At present many promising and selective herbicides are available which can control weeds effectively.

Weed competition, however, is a significant obstacle to soybean+pigeonpea intercropping, especially in the early stages of growth. Both crops are fiercely competed with by weeds for space, light, moisture, and nutrients. Pigeon pea's slow initial growth makes the situation worse because it allows weeds to emerge quickly. Research shows that up to 60 days after sowing is when crop-weed competition is most critical in pigeonpea, and that unregulated weed growth can result in significant production losses (Kaur *et al*., 2015; Chouhan and Verma, 2023) [8, 2]. Broad-leaved species like *Commelina benghalensis* and *Phyllanthus niruri*, sedges like *Cyperus rotundus*, and grasses like *Echinochloa colona* and *Digitaria spp*. make up the majority of the weed flora in these settings (Kumar; Patel *et al*., 2022) [13].

Precision agriculture is using Unmanned Aerial Vehicles (UAVs), also referred to as drones, more and more. Drones that are outfitted with GPS, sensors, and spraying units guarantee consistent and targeted herbicide delivery with less drift and chemical waste. With droplet sizes of 100-300 µm for efficient canopy penetration, they normally operate 2-4 meters above the crop canopy and carry 10-30 liters of spray solution (Huang *et al*., 2019) [6]. By covering 6-10 hectares every hour, a single drone can save money, time, and labor. Site-specific weed control is made possible by contemporary drones equipped with AI-based sensors and variable rate technology, which improves sustainability and efficiency (Zhang *et al*., 2020; Jiang *et al*., 2021) [19, 7]. Precision, safety, and environmental protection are further guaranteed by their versatility in intercropping systems such as soybean-pigeonpea (Chauhan *et al*., 2021) [3].

Materials and Methods

The present experiment was conducted during the *kharif* season of 2024-25 at Experimental Farm, Krishi Vigyan Kendra (Selsura) Wardha. An experiment was laid out in Randomized Block Design consisting of eight treatments *viz*., T_1 - Farmers practice (2 hoeing and 2 hand weeding), T_2 - Weedy check, T_3 - Pendimethalin PE 38.7% 0.677 kg a.i./ha through Drone, T_4 - Imazethapyr POE 0.075 kg a.i./ha at 15 DAS through Drone, T_5 - Imazethapyr + Imazamox POE 0.070 kg a.i./ha at 15 DAS through Drone, T_6 - Pendimethalin PE 38.7% 0.677 kg a.i./ha through Power sprayer, T_7 - Imazethapyr POE 0.075 kg a.i./ha at 15 DAS through Power sprayer and T_8 - Imazethapyr + Imazamox POE 0.070 kg a.i./ha at 15 DAS through Power sprayer. The gross plot and net plot size was 7.2 m X 4.8 m and 5.4 m X 4.0 m respectively. In accordance with the treatments, the seed of soybean variety PDKV Amba at a spacing 45 cm × 05 cm and pigeonpea variety PKV Tara at spacing of 120 cm × 30 cm were sown in corresponding plots on 28th July 2024. Weedicide were applied as per the treatments with Power sprayer and with Drone. Observations were recorded from net plot area and then adjusted to ha^{-1} value using hectare factor conversion. Statistical analysis was applied to data and cost of cultivation was estimated by using prevailing market price of soybean and pigeonpea.

Results and Discussion

Yield attributes

Seed yield

Soybean yield was significantly affected by the weed management strategies adopted, Among the herbicidal treatments, significantly higher seed yield (15.16 q ha^{-1}) was recorded with treatment T_8 Imazethapyr + Imazamox POE 0.070 kg a.i./ha at 15 DAS through Power sprayer, which was superior over the T_3, T_4, T_6, and T_7. However, it was at par with treatment T_5. This might be due to the weed managed at critical period and early crop growth, higher dry matter production, which resulted in higher production of photosynthesis, which acts as a source and greater translocation of food materials to the reproductive parts resulted in superiority of yield attributing characters and ultimately high yield. The current study supports the findings of Kumar *et al.* (2020) [9].

Pigeon pea yield was significantly affected by the weed management strategies adopted. Among the herbicidal treatments, significantly higher seed yield (8.58 q ha^{-1}) was recorded with treatment T_8 - Imazethapyr + Imazamox POE 0.070 kg a.i./ha at 15 DAS through Power sprayer study supports the findings of Patil.

Soybean Equivalent Yield (SEY) is a crucial parameter for assessing the combined productivity of intercropped species in a common economic unit. In the present study, T_1 (farmers' practice) recorded the highest SEY of 30.70 q ha^{-1}, which was significantly superior to all other treatments. This was followed by T_8 (28.40 q ha^{-1}) and T_5 (27.11 q ha^{-1}), which were statistically at par with each other and closely approached the SEY of the farmers' practice. These higher SEYs under T_1, T_8, and T_5 can be attributed to the combined effect of increased soybean and pigeonpea yields due to effective weed control and minimal inter-species competition. The same results were reported by Singh *et al*. (2021) [7].

Economics

Application of Imazethapyr + Imazamox POE 0.070 kg a.i./ha at 15 DAS through Power sprayer recorded significantly maximum GMR (Rs. 138942 ha^{-1}), NMR (Rs. 93371 ha^{-1}) and B:C ratio (3.26) and NMR was at par with T_5 - Imazethapyr + Imazamox POE 0.070 kg a.i./ha at 15 DAS through Drone which records GMR of Rs. 132637 ha^{-1}, NMR of Rs. 89466 ha^{-1} and B:C ratio (3.07). While, weedy check treatment (T_1) gave least GMR (Rs. 92675 ha^{-1}), NMR (Rs. 52555 ha^{-1}) with B:C ratio (2.31).

Conclusion

On the basis of the field experimentation, it is concluded that, Application of Imazethapyr + Imazamox POE 0.070 kg a.i./ha at 15 DAS through Power sprayer recorded significantly higher seed yield (q ha^{-1}) of Soybean, Pigeon pea and Soybean Equivalent yield also with higher net returns followed by application of T_5 - Imazethapyr + Imazamox POE 0.070 kg a.i./ha at 15 DAS through Drone.

Table 1: Seed yield of soybean, pigeon pea and soybean equivalent yield influenced by different treatment

Tr. No.	Treatment Detail	Seed yield (q ha $^{-1}$)		
		Soybean	Pigeonpea	Soybean equivalent yield (SEY)
T_1	Farmers practice (2 hoeing and 2 hand weeding)	16.72	9.06	30.70
T_2	Weedy check	10.78	5.29	18.94
T_3	Pendimethalin PE 38.7% 0.677 kg a.i./ha through Drone	11.82	7.13	22.82
T_4	Imazethapyr POE 0.075 kg a.i./ha at 15 DAS through Drone	13.27	7.32	24.57
T_5	Imazethapyr + Imazamox POE 0.070 kg a.i./ha at 15 DAS through Drone	14.72	8.03	27.11
T_6	Pendimethalin PE 38.7% 0.677 kg a.i./ha through Power sprayer	12.81	6.79	23.29
T_7	Imazethapyr POE 0.075 kg a.i./ha at 15 DAS through Power sprayer	13.65	7.59	25.36
T_8	Imazethapyr + Imazamox POE 0.070 kg a.i./ha at 15 DAS through Power sprayer	15.16	8.58	28.40
	SE (m) ±	0.49	0.22	0.48
	CD at 5%	1.49	0.66	1.47
	GM	13.62	7.47	25.15

Table 2: Economics of weed control treatment

Tr. No.	Treatment Detail	COC (Rs ha $^{-1}$)	GMR (Rs ha^{-1})	NMR (Rs ha $^{-1}$)	B:C Ratio
T_1	Farmers practice (2 hoeing and 2 hand weeding)	49320	150168	100848	3.04
T_2	Weedy check	40120	92675	52555	2.31
T_3	Pendimethalin PE 38.7% 0.677 kg a.i./ha through Drone	42670	111665	68984	2.62
T_4	Imazethapyr POE 0.075 kg a.i./ha at 15 DAS through Drone	42990	120183	77192	2.80
T_5	Imazethapyr + Imazamox POE 0.070 kg a.i./ha at 15 DAS through Drone	43170	132637	89466	3.07
T_6	Pendimethalin PE 38.7% 0.677 kg a.i./ha through Power sprayer	42390	113931	71192	2.71
T_7	Imazethapyr POE 0.075 kg a.i./ha at 15 DAS through Power sprayer	42390	124080	81690	2.93
T_8	Imazethapyr + Imazamox POE 0.070 kg a.i./ha at 15 DAS through Power sprayer	42570	138942	93371	3.26
	SE (m) ±	-	2365	2365	-
	CD at 5%	-	7173	7173	-
	GM	43162	123034	79871	2.84

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