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Pigeon pea pollination deficit in smallholder farms of Kenya

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ABSTRACT

Aim: The aim of the study was to quantify the pollination deficit of pigeon pea in farmers' fields in Lower Eastern Kenya and to assess the contribution of insect pollinators to yield and grain quality.

Materials and Methods: The study was conducted on eight farms during season one and six farms during season two. Fifteen plants were randomly selected per farm, and two terminal branches per plant with inflorescences of similar age and flower number were identified. One branch was bagged to exclude pollinators, while the other was left open to allow unrestricted visits. Pods were harvested, counted, and weighed. Yield components assessed included pod set, number and weight (g) of grains per pod and grain protein content (%).

Results: Significant differences were observed between bagged and open treatments for pod set ($p < 0.001$), grain number ($p = 0.004$), and grain weight ($p = 0.003$). Unrestricted pollination increased pod set by 201.3%, grain number per pod by 23.07%, and seed weight per pod by 17.34%. Mean pod weight increased by 19.01%. Grain protein content was higher in un-bagged inflorescences (22.5%) compared to bagged ones (19.3%), indicating a 16.58% increase due to insect pollination. Season one grains showed higher protein content (22.51%) than season two (16.05%).

Conclusion: It was concluded that insect pollination significantly enhances pigeon pea yield and grain quality. Promoting pollinator activity in pigeon pea fields may be recommended to improve productivity and nutritional value.

Keywords: Insect pollinators, pigeon pea, pollination deficit, protein content, yield

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Introduction

Insect pollination is widely recognized as a vital ecosystem service supporting global agricultural productivity (Smith *et al*., 2011; Winfree *et al*., 2011). Among pollinating taxa, bees constitute the most significant group, contributing substantially to both yield quantity and quality across diverse cropping systems (Greenleaf *et al*., 2006; Winfree *et al*., 2007). However, emerging evidence highlights the complementary role of non-bee insects such as flies, beetles, butterflies, and wasps in pollination, particularly in diversified agroecosystems (Rader *et al*., 2016). Collectively, these pollinator groups enhance and stabilize crop-pollination services (Garibaldi *et al*., 2013), and declines in their populations could reduce global crop yields by approximately 40%.

Land-use changes, habitat fragmentation, and intensive agricultural practices have been identified as major drivers of pollinator declines worldwide (Garibaldi *et al*., 2014; Ollerton *et al*., 2014). While developed regions such as the United States, Europe, China, and Japan largely depend on managed pollinators to sustain high-value crops, smallholder systems in developing regions including India, South Asia, and sub-Saharan Africa rely heavily on natural pollinators to produce nutrient-rich food crops (Ken *et al*., 2012)

Research assessing the quantitative contribution of insect pollinators to crop yield and quality has been extensively conducted in Europe and North America (Bommarco *et al*., 2012; Klatt *et al*., 2014). In contrast, studies in Africa have mainly focused on fruit (Carvalheiro *et al*., 2010; Carvalheiro *et al*., 2012) and seed crops (Melin *et al*., 2014; Carvalheiro *et al*., 2011), with limited attention to leguminous crops in smallholder systems (<2 ha) that dominate sub-Saharan agriculture (Steward *et al*., 2014; Garibaldi *et al*., 2016).

Pigeon pea (*Cajanus cajan* L.), an open-pollinated legume of major nutritional and economic importance, benefits significantly from insect pollination, particularly by bees (Abrol& Shankar, 2015). Despite this, studies have reported persistent pollination deficits in pigeon pea even under field conditions with natural pollinator presence (Pando *et al*., 2011). To address this gap, the present study was undertaken to quantify the pollination deficit of pigeon pea in farmers' fields in Lower Eastern Kenya and to assess the contribution of insect pollinators to yield and grain quality.

Materials and Methods

The study was conducted in Machakos County, Eastern Kenya (Fig. 1). The county lies between latitudes 0°45′S and 1°31′S and longitudes 36°45′E and 37°45′E, within a semi-arid to arid agro-ecological zone (Huho, 2017). The area experienced mean annual temperatures ranging from 9.1°C to 26.7°C and receives between 500 mm and 900 mm of rainfall annually. Altitudes range from 1,000 to 1,600 meters above sea level (Thiong'o, 2016).

Pigeon pea (*Cajanus cajan* L.) variety Mbaazi II was used for the experiment. Certified seeds treated with an appropriate seed dresser were obtained from the Kenya Agricultural and Livestock Research Organization (KALRO)–Katumani. Sowing was carried out at the onset of the rainy season, following the recommended spacing of 100 cm between rows and 50 cm between plants to ensure optimal crop growth and yield performance.

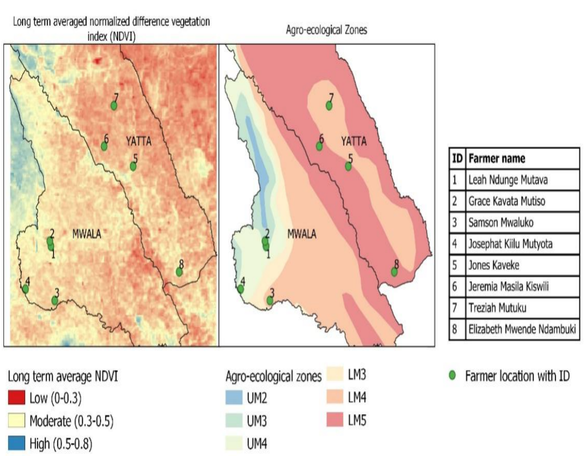

Fig 1: Study site map (Matolo Nyamai, 2023)

A Randomized Complete Block Design (RCBD) was employed for this study. In Season One (October 2020 – September 2021), eight farms (blocks) of approximately one acre each were used, while six farms were included in Season Two (November 2021 – September 2022). Within each farm, fifteen pigeon pea (*Cajanus cajan* L.) plants were randomly selected for experimentation.

On each plant, two terminal branches bearing inflorescences of similar age and number of flower buds were identified and assigned to two treatments:

1. Bagged treatment – inflorescences were enclosed in fine-mesh bags to exclude flower visitors.
2. Open treatment – inflorescences were tagged and left un-bagged to allow unrestricted access by insect pollinators.

When flowering ended, the bags were removed, and the number of pods per terminal branch was recorded. Data collection continued until harvest, when the number and weight (g) of pods per terminal branch, and the number and weight (g) of grains per pod/terminal branch were evaluated and protein analyses done to quantify pollination deficit.

Data were analysed using Student's t-test at the 0.05 level of significance (appropriate for two-treatment comparisons) in GenStat Discovery Edition 15. Means were separated using the Student–Newman–Keuls (SNK) test at $P \leq 0.05$ to determine significant differences between treatments. Results were summarized in tables and graphs comparing yield parameters between bagged and un-bagged terminal branches.

Results and Discussion

The study revealed significant effects of insect pollination on pigeon pea yield components. There were highly significant differences (p = 0.004, p = 0.003) in both the number and weight (g) of pods harvested per terminal branch between treatments. Un-bagged (open-pollinated) terminal branches produced a mean of 45 pods, whereas bagged branches yielded only 15 pods. Similarly, pod weight was substantially higher in un-bagged branches (56.84 g) compared to bagged ones (15.97 g). This represents a 200% increase in pod number and a 255.92% increase in pod weight under open pollination conditions (Table 1).

Table 1: Mean number & weight (g) of pigeon pea pods per terminal branch, single pod weight (g), number & weight (g) of grains per pod and number & weight (g) of undamaged grains per pod.

Pollination type	No pods per terminal branch	Weight (g) of pods per terminal branch	Single pod weight (g)	No grains per pod	Weight (g) of grains per pod	No undamaged grains per pod	Weight (g) undamaged grains per pod
Bagged	15.00±2.87	15.97±3.93	1.05±0.04	3.77±0.12	0.65±0.03	2.45±0.14	0.53±0.03
Un bagged	45.18±8.79	56.84±11.17	1.25±0.02	4.64±0.07	0.76±0.02	2.94±0.08	0.64±0.02
t-value	-3.26	-3.45	-4.53	-6.58	-3.34	-3.11	-2.98
df	19.37	19.9	1028	1028	1028	1028	1028
p-value	0.004	0.003	< 0.001	< 0.001	< 0.001	0.002	0.003

Significant differences ($p< 0.001$) were also observed for key yield parameters: single pod weight, number of grains per pod, and weight of grains per pod. Un-bagged terminal branches recorded higher values (1.252 g, 4.636 grains, and 0.076 g, respectively) compared to bagged branches (1.052 g, 3.767 grains, and 0.649 g). These correspond to increases of 19.01%, 23.07%, and 17.34%, respectively (Table 1).

A similar trend was observed for undamaged grains per pod, where un-bagged terminal branches produced a mean of 2.94 grains per pod compared to 2.45 grains in the bagged treatment. The corresponding grain weights were 0.639 g and 0.530 g, respectively, both showing highly significant differences (p = 0.002, p = 0.003). This represents 20.12% and 20.60% increases in the number and weight of undamaged grains, respectively (Table 1).

Furthermore, pigeon pea grains from open-pollinated branches exhibited a higher protein content (22.5%) compared to those from bagged branches (19.3%), translating to a 16.58% increase in protein content (Fig. 2). This result confirms that unrestricted insect visitation significantly enhances both yield and grain nutritional quality in pigeon pea.

During the study, protein content (%) of pigeon pea grains was analyzed across the two cropping seasons. Results revealed a highly significant difference ($p< 0.001$) between seasons, with mean protein contents of 22.51% in season one and 16.05% in season two. This represented a 40.2% variation in protein content between the two seasons (Fig. 3). The higher protein concentration in season one may be attributed to more favorable environmental conditions, such as adequate rainfall and moderate temperatures, which likely enhanced nutrient assimilation and seed development. Conversely, the lower protein levels observed in season two could be associated with increased heat and moisture stress, which may have limited nitrogen uptake and metabolic efficiency during pod filling.

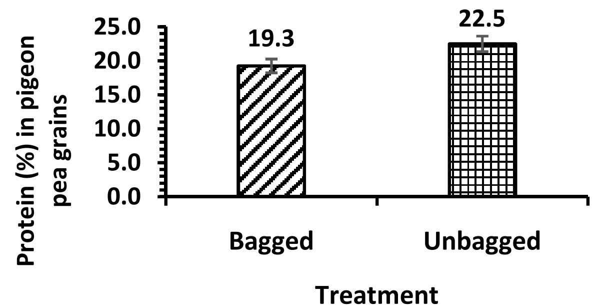

Fig 2. Percent protein content in pigeon pea grains as influenced by pollinators in lower eastern Kenya

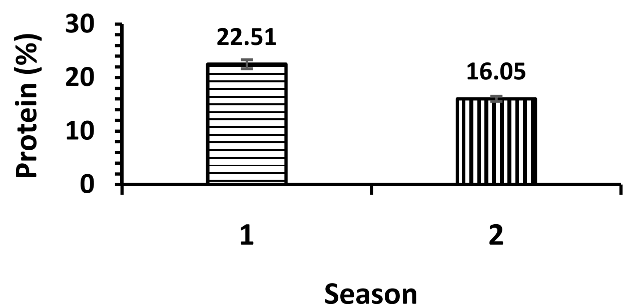

Fig 3. Percent protein content in pigeon pea grains for season one and two in lower eastern Kenya

The observed increase in pod set during this study aligns with the findings of Mulwa *et al.* (2019), who reported a 65.4% pollination deficit in avocado yields in Murang'a County, Kenya, emphasizing the crucial role of insect pollinators in yield formation. Similarly, other studies showed that pollinators significantly enhance the productivity of citrus fruits such as oranges (Sanford, 2011), grapefruits (Chacoff and Aizen, 2007), and tangelos (Silva da Santos *et al.*, 2021), as well as improve fruit set, sugar content, and size in various mandarin varieties (Yildiz and Kaplankiran, 2017).

In the present study, the podding rate, number and weight of grains per pod, and the quantity of undamaged grains were all significantly higher in un-bagged inflorescences compared to those protected from insect visits. These findings were consistent with Singh (2016), who reported similar increases in yield parameters of pigeon pea in India following insect pollination. Furthermore, higher protein content was recorded in grains from inflorescences exposed to unrestricted pollinator visitation, in agreement with Klatt *et al.* (2014), who found that wild bee pollination enhances seed set, quality, and commercial value in various crops.

The variation in yield and protein content between the two seasons could be attributed to fluctuations in agro-climatic conditions, including temperature and soil moisture availability, which influence pollen viability and flower retention (Iizumi and Ramankutty, 2016).

Conclusions

It was concluded that both the quantity and quality of pigeon pea yields are significantly improved when flowers are accessible to insect pollinators. Farmers are therefore encouraged to conserve and protect pollinator habitats, avoid harmful pesticide use during flowering, and adopt pollinator-friendly practices to enhance grain yield and quality.

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References

Abrol DP and Shankar U (2015). Pollination biology and foraging behavior of bees on pigeon pea (*Cajanus cajan* L.). J. Apic. Res., 54(5): 394–401.

Bommarco R, Marini L and Vaissière BE (2012). Insect pollination enhances seed yield, quality, and market value in oilseed rape. Oecologia, 169(4): 1025–1032.

Carvalheiro LG, Seymour CL, Veldtman R and Nicolson SW (2010). Pollination services decline with distance from natural habitat even in biodiversity-rich areas. J. Appl. Ecol., 47(4): 810–820.

Carvalheiro LG, Seymour CL, Nicolson SW and Veldtman R (2011). Pollination services decline with distance from natural habitat even in biodiversity-rich areas. J. Appl. Ecol., 48(3): 810–820.

Carvalheiro LG, Seymour CL, Nicolson SW and Veldtman R (2012). Creating patches of native flowers facilitates crop pollination in large agricultural fields: Mango as a case study. J. Appl. Ecol., 49(6): 1373–1383.

Chacoff NP and Aizen MA (2007). Pollination and fruit set in citrus: A case study with grapefruit. Ann. Bot., 100(4): 499–506.

Garibaldi LA, Steffan-Dewenter I, Winfree R, Aizen MA, Bommarco R, Cunningham SA and Klein AM (2013). Wild pollinators enhance fruit set of crops regardless of honeybee abundance. Science, 339(6127): 1608–1611.

Garibaldi LA, Carvalheiro LG, Leonhardt SD, Aizen MA, Blaauw BR, Isaacs R and Klein AM (2014). From research to action: Enhancing crop yield through wild pollinators. Front. Ecol. Environ., 12(8): 439–447.

Garibaldi LA, Gemmill-Herren B, D'Annolfo R, Graeub BE, Cunningham SA and Breeze TD (2016). Farming approaches for greater biodiversity, livelihoods, and food security. Trends Ecol. Evol., 32(1): 68–80.

Greenleaf SS, Williams NM, Winfree R and Kremen C (2006). Bee foraging ranges and their relationship to body size. Oecologia, 153(3): 589–596.

Iizumi T and Ramankutty N (2016). Changes in yield variability of major crops for 1981–2010 explained by climate change. Environ. Res. Lett., 11(3): 034003.

Ken R, Bhattacharya P and Nair PK (2012). Pollination management and sustainable agriculture in developing countries. Agric. Syst., 109: 1–6.

Klatt BK, Holzschuh A, Westphal C, Clough Y, Smit I, Pawelzik E and Tscharntke T (2014). Bee pollination improves crop quality, shelf life, and commercial value. Proc. R. Soc. B Biol. Sci., 281(1775): 20132440.

Melin A, Seymour CL and Veldtman R (2014). High proximity to natural vegetation is important for pollination services in smallholder avocado orchards in South Africa. J. Appl. Ecol., 51(4): 1103–1113.

Mulwa JM, Kinuthia WK, Ndegwa PN, Gikungu MW and Kilonzo JN (2019). Pollination deficit and avocado yield loss associated with pollinator decline in Murang'a County, Kenya. Afr. J. Agric. Res., 14(22): 931–940.

Ollerton J, Winfree R and Tarrant S (2014). How many flowering plants are pollinated by animals? Oikos, 120(3): 321–326.

Pando JB, Bello AO and Alabi O (2011). Pollination deficit and reproductive success of pigeon pea (*Cajanus cajan* L.) in farmer-managed fields. Afr. J. Agric. Res., 6(28): 6025–6031.

Rader R, Bartomeus I, Garibaldi LA, Garratt MPD, Howlett BG, Winfree R and Woyciechowski M (2016). Non-bee insects are important contributors to global crop pollination. Proc. Natl. Acad. Sci., 113(1): 146–151.

Sanford MT (2011). Pollination and fruit set in orange production. *Univ. Florida IFAS Ext. Publ.*, 9(2): 1–5.

Silva da Santos LM, Oliveira RF and Vieira EM (2021). Pollination effect on fruit set and quality of tangelo (*Citrus* × *tangelo*). *Rev. Bras.* Frutic., 43(4): e-726.

Singh R (2016). Role of pollinators in pigeon pea (*Cajanus cajan*) yield improvement in India. Int. J. Plant Sci., 11(2): 45–52.

Smith P, Gregory PJ and van Noordwijk M (2011). Sustainable food production and environmental sustainability. Philos. Trans. R. Soc. B Biol. Sci., 365(1554): 2943–2959.

Steward PR, Shackelford G, Carvalheiro LG, Benton TG, Garibaldi LA, Sait SM and de Palma A (2014). Pollination and biological control research: Are we neglecting two billion smallholders? Agric. Ecosyst. Environ., 201: 84–89.

Winfree R, Aguilar R, Vázquez DP, LeBuhn G and Aizen MA (2007). A meta-analysis of bees' responses to anthropogenic disturbance. Ecology, 90(8): 2068–2076.

Winfree R, Gross BJ and Kremen C (2011). Valuing pollination services to agriculture. Ecol. Econ., 71(1): 80–88.

Yildiz E and Kaplankiran M (2017). The role of pollinators in improving mandarin (*Citrus reticulata*) fruit set and quality. Turk. J. Agric. For., 41(5): 370–378.

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