Fodder Crop Adoption through Push-Pull Technology (PPT) for Fall Armyworm (FAW) Control in Cereals Cropping Systems

Michael N. Njunie
Kenya Agricultural and Livestock Research Organisation, Kenya

E. N. Muthiani
Kenya Agricultural and Livestock Research Organisation, Kenya

A. Mzingirwa
Kenya Agricultural and Livestock Research Organisation, Kenya

N. F. Pole
Kenya Agricultural and Livestock Research Organisation, Kenya

B. M. Muli
Kenya Agricultural and Livestock Research Organisation, Kenya

See next page for additional authors

The XXIV International Grassland Congress / XI International Rangeland Congress (Sustainable Use of Grassland and Rangeland Resources for Improved Livelihoods) takes place virtually from October 25 through October 29, 2021.

Proceedings edited by the National Organizing Committee of 2021 IGC/IRC Congress

Published by the Kenya Agricultural and Livestock Research Organization

Presenter Information

Michael N. Njunie, E. N. Muthiani, A. Mzingirwa, N. F. Pole, B. M. Muli, and A. O. Esilaba

Fodder crop adoption through push-pull technology (PPT) for fall armyworm (FAW) control in cereals cropping systems

Njunie, MN*; Muthiani, EN†; Mzingirwa, A.±; Pole, NF* Muli, BM± and Esilaba, A.O‡

* Kenya Agricultural and Research Organization (KALRO) Matuga, PO Box 4-80406, Matuga, Kenya;
†KALRO Mariakani, PO Box 30, Mariakani, Kenya;
±KALRO Mtwapa, PO Box 16 Mtwapa -80109;
‡KALRO Headquarters, PO Box 57811, NAIROBI, 00200, Kenya

Abstract
There is an urgent need to increase grain yields and animal products due to increasing human population in Africa. Push-pull technology (PPT) is a conservation agriculture intercrop technology which protects and enhances natural resources productivity and ecosystem services in mixed farming systems. The technology involves growing of a cereal crop with a repellent intercrop, *Desmodium* genus (silverleaf, *D. uncinatum* and greenleaf, *D. intortum*) with grass such as *Pennisetum purpureum* or *Brachiaria* spp. planted as a border around the cereal-legume intercrop. The plants accompanying the cereal crop are typically valuable high quality fodder thus integrating crop-livestock production. The PPT was initially developed in the high altitude areas which were mainly suitable for optimal growth of *Desmodium* sp. In contrast, *Clitoria ternatea* (Blue pea) is the recommended herbaceous forage legume crop for the low altitude areas. In addition, clitoria and dolichos demonstrated their ability to effectively repel stem-borer pests in push pull technology systems within the coastal lowlands. The experiments were established in four sites representing diverse coastal lowlands (CL) agro-ecological zones (CL3, CL4, and CL5). The species used in the system were: maize (cereal crop, the main target by *Spodoptera* pests); climate-smart brachiaria grass (as a pull crop) and blue pea (as a push crop). It was demonstrated that the push-pull technology can also control FAW and that this system be promoted for provision of high quality fodder for livestock in smallholder mixed farms.

Key words: [push-pull technology; fodder; adoption; lowlands]

Introduction
Alongside other parts of coastal lowlands in East Africa, the coastal region of Kenya has potential for dairy production due to demand for fresh milk and other dairy products from a rapidly growing urban and rural population. Seasonal feed shortages and inadequate nutrient concentrations to support dairy production were reported in Muinga *et al*., 1999. Despite the efforts by Government of Kenya working with other stakeholders to promote cultivated forages for dairy cows in the region, adoption of improved fodder crops production is low the region and natural vegetation are the main source of livestock feed (Njarui et al. 2016).

Cereals, mainly maize, sorghum, millet and rice, are the main staple and cash crops for small-scale farmers in Kenya contributing to food and nutrition security. However, the yields of these crops are under threat from the Fall armyworm (FAW), *Spodoptera frugiperda* (J E Smith) which invaded east African region in 2017 and caused substantial damage to cereal production in the East African region (Kumela et al. 2018). The push-pull technologies for pest, soil fertility and Striga weed control (Khan *et al,* 2007) have been cited as a promising method of FAW control in the East African region (Midega et al., 2018). The PPT involves the use of forage legumes (*Desmodium* spp, *Clitoria ternatea* and *Lablab purpureus*) as a repellent of moth (push) and bordering fodder grass (Brachiaria species, *Panicum spp*, and Napier grass) to attract the moth (pull) (Njunie et al, 2014). The inclusion of fodder crops in the PPT system implies that the technology has potential of reversing seasonal feed shortages in mixed farming systems. This study was established to validate the use of PPT for FAW control, and also highlight the feed production component in the PPT cropping systems.

Materials and methods
The study was carried out in coastal lowland Kenya in CL3, CL4 and CL5 agro-ecological zones. The soil and climatic conditions are described by Jaetzold and Schmidt, 2006. Matuga and Mtwapa sites are in the coconut cassava (CL3) agro-ecological zone, Msabaha is in the cashew nut-cassava (CL4) while Mariakani is in the livestock millet zone (CL5). The annual rainfall ranges from 1000 to 1230 mm in CL3, 800 to 1100 in CL4 and 600 to 900 mm in CL5. The soils are well drained, deep, low in available nutrients, and have low to moderate moisture storage capacity. The trial was established on station at three centres and in 12 sites on-

farm across Kilifi and Kwale counties. Two levels of fertilizer rate were applied (no fertilizer control and half recommended manure/fertilizer rates). The five cropping systems studied were: sole maize, sole cowpea, maize-cowpea intercrop, maize-clitoria intercrop and maize-cowpea-clitoria intercrop. The crops systems were planted with or without a brachiaria grass border around the cropping system. The trial was laid in a split -plot design with fertilizer rates as the main plots and cropping systems as the subplots. The design was Randomized Complete Block Design (RCBD). The on-station trial was replicated 4 times and the experimental plots measured 6m by 6m. .

Establishing PPT trials

Brachiaria Mulatto II grass (the "pull" crop) seed was sown along the outer border of the 6m by 6 m plot dimensions. Seed was drilled along rows 50 cm apart, at 20 cm intervals within the row. Clitoria (the "push" legume crop) was sown between every third and fourth rows of maize. The first row of maize was 1 m away from the inner row of Brachiaria grass. Maize crop spacing was 75 cm by 25 cm. Cowpea was planted spaced 50 cm by 20 cm. The first row of cowpea was sown 1 m away from the inner row of the brachiaria grass. In the maize-cowpea intercrop, the maize was sown at a spacing was 75 cm by 25 cm. Cowpea was intercropped between maize rows, without replacement. In the maize-cowpea-clitoria intercrop, clitoria was planted after every three maize rows, replacing a cowpea row.

Fertilizer was applied at two levels (no fertilizer control, full and half recommended manure/fertilizer rates) applied in the planting holes. The half fertilizer rates was 20 kg N/ha, 20 kg P_2O_5/ha and 2.5 t/ha of manure equivalent.

Trial management

The push and pull crops being perennials are established once at the beginning of the first cropping season and are cutback at the beginning of every new annual crops planting season (Midega *et al.*, 2015).

Brachiaria grass was harvested at 3 months old or 1-1.5 m high after planting and used as fodder, harvesting started with the inner row nearest the maize, all around the field. Stubble height of 10 cm above ground was left at harvesting. The second row was harvested only when the inner row attained 1-1.5 m high to ensure the presence of "pull" or trap during the maize growing stage.

Data collection and measurement

The methodology used for assessing pest damage was adapted from Midega *et al.*, 2018. Fall army worm incidence, severity of damage and number of FAW larvae present in a plant were assessed during the maize crop growth stage at one week intervals beginning at two weeks after germination up to tasselling (at two weeks after first ear (2WAE). Severity damage by FAW was recorded for five randomly selected maize plants per plot, score range of 1-6 (where: 1=clean; 6= most severe). To assess the number of larvae per plant, five maize plants were collected at random per plot for destructive analysis.

At harvest, cob count per net plot was done. Field weight of the cobs was recorded. Shelling fraction was determined for every plot and field moisture content of the grain recorded to compute the grain yield per hectare at 13.5% moisture content. The plant count and compensation method was also used to get number of plants per plot. Maize stover was harvested from a net plot measuring 2.25 by 4.5 m. The plants were cut at ground level, weighed, and samples taken for dry matter determinations.

Results

Fall armyworm (FAW)

Based on the rating scale by Midega et al, 2018, rating of FAW incidence ranged from none to low (0 to <25% plants with fall armyworm larvae) to high (>75% plants incidence). Very high incidence (>75% plants) was observed in all sole maize cropping systems without the PPT component crops (Table 1). Low incidence (<25%) was observed for sole-maize and maize-cowpea cropping system without fertilizer treatment and full PPT plant components. The low incidence of FAW in nearly all the cropping systems with full PPT (maize +clitoria +brachiaria grass border) implies that this PPT system was effective in FAW control. The trend and severity of FAW damage on maize crop and larval counts were similar to that observed for incidence ratings.

Table 1. Monitoring incidence of FAW incidence, larvae counts and severity scores recorded on maize at Mtwapa during 2019 long rain season

cropping system	FAW incidence	Severity	Larvae
	%	Mean score	mean per plant
Sole Maize no fertilizer	87.5 a*	1.5 abc	0.1 bc
Sole maize- fertilizer+ brachiaria border	85.0 a	1.8 ab	0.3 a
Sole Maize +fertilizer	77.5 a	1.8 ab	0.2 ab
Maize- cowpea +fertilizer+ brachiaria border	77.5 a	1.4 bcd	0.1 bc
Sole maize + brachiaria border	67.5 ab	1.3 cd	0 c
Maize- cowpea -+ brachiaria border	67.5 ab	1.3 cd	0.1 bc
Maize +fertilizer – clitoria-brachiaria border (PPT)	62.5 ab	1.4 cd	0 c
Maize cowpea +fertilizer- clitoria-brachiaria border (PPT)	42.5 bc	1.3 cd	0 c
Maize no fertilizer - clitoria-brachiaria border (PPT)	35 c	1.1 d	0.1 bc
Maize- cowpea no fertilizer - clitoria-brachiaria border (PPT)	17.5 cd	1.3 cd	0 c
Sole cowpea no fertilizer + brachiaria border	0 d	0 e	0 c
Sole cowpea +fertilizer + brachiaria border	0 d	0 e	0 c

Key: *figures followed by different superscripts are significantly different

Effect of cropping system on maize grain and stover yields

The effects of cropping systems in different sites and seasons are summarized in Table 2. Generally, performance of the maize crop under various intercropping systems was poor, as reflected in maize and stover yields across the sites and seasons. However, grain and stover yield were highest in the sole maize cropping system compared to intercrops. The sole maize cropping system had minimal competition for nutrients and soil moisture compared to other treatments.

Effect of cropping system on fodder yield

The yields of brachiaria and clitoria are presented in Table 2. The yields of border rows were not significantly influenced by the cropping system. As expected, higher yields were recorded in the more sub-humid agro ecological zone CL3 compared to the semi arid CL5 (means CL3=4.9; CL5 = 0.3 t ha^{-1}). The forage legume yield was much lower than for the grasses due to competing effects of component crops (means CL3=1.0; CL5 = 0.6 t ha^{-1}). The forages harvested at different times can be fed to ruminant livestock.

Discussion and implication of the results

The FAW monitoring results clearly show that the push legume clitoria and pull grass brachiaria were effective in controlling FAW in the maize cropping systems. Previous research in the region reported by Njunie et al. 2014 had demonstrated the effectiveness of *Clitoria ternatea* as a push of stem borers from maize crop while using Napier grass as the trap crop. These results confirm that the push-pull technology using clitoria legume and brachiaria grass can also control FAW.

In addition, forage harvested from the trap crop borders and the legumes intercropped with the cereal crop are proven high quality feeds for livestock and contribute to seasonal fodder availability. Improved animal performance has been recorded where brachiaria grasses were fed to lactating dairy cattle and growing galla goats (Njarui et al, 2016). Increased milk production has been recorded where lactating dairy cattle were fed Napier grass cv. Bana supplemented with forage legumes (Juma *et al*., 2006).

It is hereby suggested that the PPT be promoted for integrated pest and soil fertility management in cereals, along with increased feed for livestock and food production.

Table 2. Effects of cropping system on yield of maize in different agro-ecological zones and seasons.

Cropping system	CL3 Mtwapa		Matuga CL3		CL5 Mariakani	
	LR 2019	SR 2019	LR 2019	SR 2019	LR 2019	SR 2019
	Maize grain (t/ha)					
Sole maize	4.8 a[‡]	2.0 a	-[±]	0.1	-	4.1 a
Sole Maize-brachiaria border	1.7 ab	0.3 ab	-	0.0	-	2.4 ab
Maize-clitoria-brachiaria border (PPT)	1.2 b	0.1 b	-	0.0	-	1.8 b
Maize-cowpea- brachiaria border	0.9 b	0.1 b	-	0.1	-	0.8 b
Maize-pulse- clitoria-brachiaria border (PPT)	0.8 b	0.3 b	-	0.0	-	0.7 b
	Maize stover yield (t/ha)					
Sole maize	-	-	4.7 a	0.7 a	0.3	2.3
Sole Maize-brachiaria border	-	-	2.8 b	-	0.2	1.3
Maize+clitoria-brachiaria border (PPT)	-	-	2.9 b	0.2 b	0.0	1.1
Maize-cowpea+ brachiaria border	-	-	1.8 b	0.3 b	0.1	1.1
Maize-cowpea-clitoria+brachiaria border (PPT)	-	-	1.6 b	0.1 b	0.0	1.1
	Brachiaria yield (t/ha)					
Sole Maize-brachiaria border	-	-	-	4.11	-	0.26
Sole cowpea brachiaria border	-	-	-	5.37	-	0.26
Maize+clitoria-brachiaria border (PPT)	-	-	-	4.43	-	0.23
Maize-cowpea+ brachiaria border	-	-	-	5.42	-	0.29
Maize-cowpea-clitoria +brachiaria border (PPT)	-	-	-	5.01	-	0.23
	Clitoria yield (t/ha) [Ŧ]					
Maize-cowpea-clitoria +brachiaria border (PPT)	-	-	-	0.91	-	0.42
Maize+clitoria-brachiaria border (PPT)	-	-	-	1.10	-	0.70

Key: [‡]figures followed by different superscripts are significantly different; [±] Information not captured during the season

[Ŧ] Yield captured for the cropping systems with the "push" legume

Acknowledgements

The research work was carried out under Kenya Cereals Enhancement Programme-Climate Resilient Agriculture Livelihood Window (KCEP-CRAL) funded by the International Fund for Agricultural Development (IFAD). The contributions by research and technical staff at Matuga, Mtwapa and Mariakani KALRO centres are gratefully acknowledged. The authors also acknowledge support from the Director-General KALRO

References

Jaetzold, R., Schmidt, H., Hornetz B., and Shisanya C. 2006. Farm Management Handbook of Kenya Vol. II: Natural Conditions and Farm management Information. 2nd edition Part C East Kenya Subpart C2 Coast Province: Ministry of Agriculture, Kenya

Juma H. K., Abdulrazak, S. A., Muinga, R. W. and Ambula, M. K. 2006. Evaluation of Clitoria, Gliricidia and Mucuna as nitrogen supplements to Napier grass basal diet in relation to the performance of lactating Jersey cows Livestock Science 103:23– 29

Khan Z. R., F. N. Muyekho, E. Njuguna, J. A. Pickett, L. J. Wadhams, J. Pitcher, A. Ndiege, G. Genga, D. Nyagol and C. Lusweti A. 2007. Primer on Planting and Managing 'Push-Pull' Fields for Stemborer and Striga Control in Maize: A Step-by-Step Guide for Farmers and Extension Staff. 2nd edition in illustrated form. First published in 2005. ISBN:92 9064 1959. 48 pp

Teshome Kumela, Josephine Simiyu, Birhanu Sisay, Paddy Likhayo, Esayas Mendesil, Linnet Gohole & Tadele Tefera (2019) Farmers' knowledge, perceptions, and management practices of the new invasive pest, fall armyworm (*Spodoptera frugiperda*) in Ethiopia and Kenya, International Journal of Pest Management, 65:1, 1-9, DOI: 10.1080/09670874.2017.1423129

Midega, C.A.O., Pittchar, J.O., Pickett, J.A., Hailu, G.W. and Khan, Z.R. (2015a). A climate-adapted push-pull system effectively controls fall armyworm, Spodoptera frugiperda (J E Smith), in maize in East Africa. *Crop Protection* 105, 10-15.

Midega, C.A.O., Bruce, T.J., Pickett, J.A., Khan, Z.R., (2015b). Ecological management of cereal stem borers in African smallholder agriculture through behavioural manipulation. Ecol. Entomol. 40 (Suppl. 1), 70–81.

Muinga, R. W., Bimbuzi, S and Mambo, L. C. (1999).Nutrient composition of locally available feedstuffs in coastal lowland Kenya. In: Kenya Agricultural Research Institute. Proceedings of the 6th Biennial KARI Conference, Nairobi, Kenya, 8-13 November 1998. pp. 287-293

Njarui, D. M. G., Gichangi, E. M., Ghimire, S. R. and Muinga, R. W. (Eds) 2016. Climate Smart Brachiaria Grasses for Improving Livestock Production in East Africa – Kenya Experience. Proceedings of the workshop held in Naivasha, Kenya, 14 - 15 September, 2016. Nairobi, Kenya. 271 p.

Njarui M G, Gichangi E M, Gatheru M, Nyambati E M, Ondiko C N, Njunie M N, Ndungu K W, Kiiya W, Kute C A O and Ayako W 2016. A comparative analysis of livestock farming in smallholder mixed crop-livestock systems in Kenya: 2. Feed utilization, availability and mitigation strategies to feed scarcity. Livestock Research for Rural Development. Volume 28, Article #066. Retrieved from http://www.lrrd.org/lrrd28/4/njar28067.html

Njunie M.N., Mzingirwa A. and Ramadhan A., (2014). Identification of alternative forage legumes for push-pull technology in coastal lowlands Kenya. In: Proceedings of EAAPP Mini-Conference and stakeholders' open day (Muinga R., Wandera F., Ouda J., Maina J., Ilatsia E., Kariuki J., Onyango ., and Waineina R. Eds.). 12-15 November 2013. RDCoE/Morendat Training Centre, Naivasha, Kenya. pp 50-55