Implications of natural refuges for Bt crops refuge requirements in developing countries

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Implications of unstructured refuges for structured refuge requirements in Bt crops: A case of Bt cotton in India

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INTRODUCTION

- It has now been documented by a number of studies (Huang et al. 2010; Singla, Johnson, and Misra 2013; Ravi et al. 2005; Qiao et al. 2010; Gustafson, Head, and Caprio 2006) that other crops grown near to Bt crops can provide refuge acreage to delay pest resistance in Bt crops by supporting target pest populations. These other crops planted next to Bt crops are voluntary and serve as 'unstructured refuges'. Such refuges are distinct from the more common mandatory, structured refuges where Bt and non-Bt varieties of the same crop are planted next to each other.
- When the Environmental Protection Agency (EPA) had mandated the 80:20 and 95:5 refuge policies for Bt crops, their recommendations were based on monocropped cropping pattern in the U.S. The regulators in many developing countries asked farmers to follow the same policy when the Bt crops were introduced in their countries. They completely ignored the fact that the farms are small and highly fragmented in their countries, where many cotton bollworm (CBW) host crops are planted alongside the Bt crops thus providing unstructured refuges to the Bt crops. It has also been indicated by satellite mapping studies in India that these refuge crops make up a substantial portion of the land area (Ravi et al, 2005).
- To date there are only few studies (Qiao et al. 2010; Qiao et al. 2009; Singla 2010; Singla, Johnson, and Misra 2013) that examined mandatory structured refuge requirements and evolution of pest resistance in bollworm pests to Bt toxin in developing countries using models that account for natural and unstructured refuges. These studies, however, consider all unstructured refuge crops together in the model and do not quantify the individual contributions of various unstructured refuge crops in decreasing the costs of refuge requirements by delaying the pace of resistance evolution in target pest. Moreover, there is no study evaluating and ranking various unstructured refuge crops grown by farmers. The present study makes an attempt to fill these gaps by separating out the individual costs/returns of major unstructured refuge crops planted alongside Bt cotton in India where farms are usually small and highly fragmented i.e. they are located in non-contiguous zones.
- The specific objectives of the study are: (1) to examine individual economic significances of seven important unstructured refuge crops in evaluating structured refuge requirements for Bt cotton grown in central and south India, under a scenario of potential resistance development in *Helicoverpa armigera* (the CBW) to Bt toxin (2) to rank order various unstructured refuges based on their net returns.

METHODS

- The methods and procedures that are used to evaluate refuge requirements consist of a biological model and an economic model. The biological model estimates the development of resistance in the pest population to the Bt toxin and pyrethroid insecticides, when the Bt crop is planted near its non-Bt counterpart and unstructured refuge crops. The economic model consists of two parts: the production model and the regulatory model. The production model examines the effects of resistance and refuges on a representative farm. The regulatory model, however, evaluates static optimal refuge sizes that maximize discounted profits over a time horizon.

DATA/PARAMETERS

- A variety of biological and economic parameters for cotton and unstructured refuges were used in the bio-economic model. The parameter values were obtained from relevant literature and experts. Major parameters were subjected to a careful sensitivity analysis by testing other plausible values of the parameters in the model.

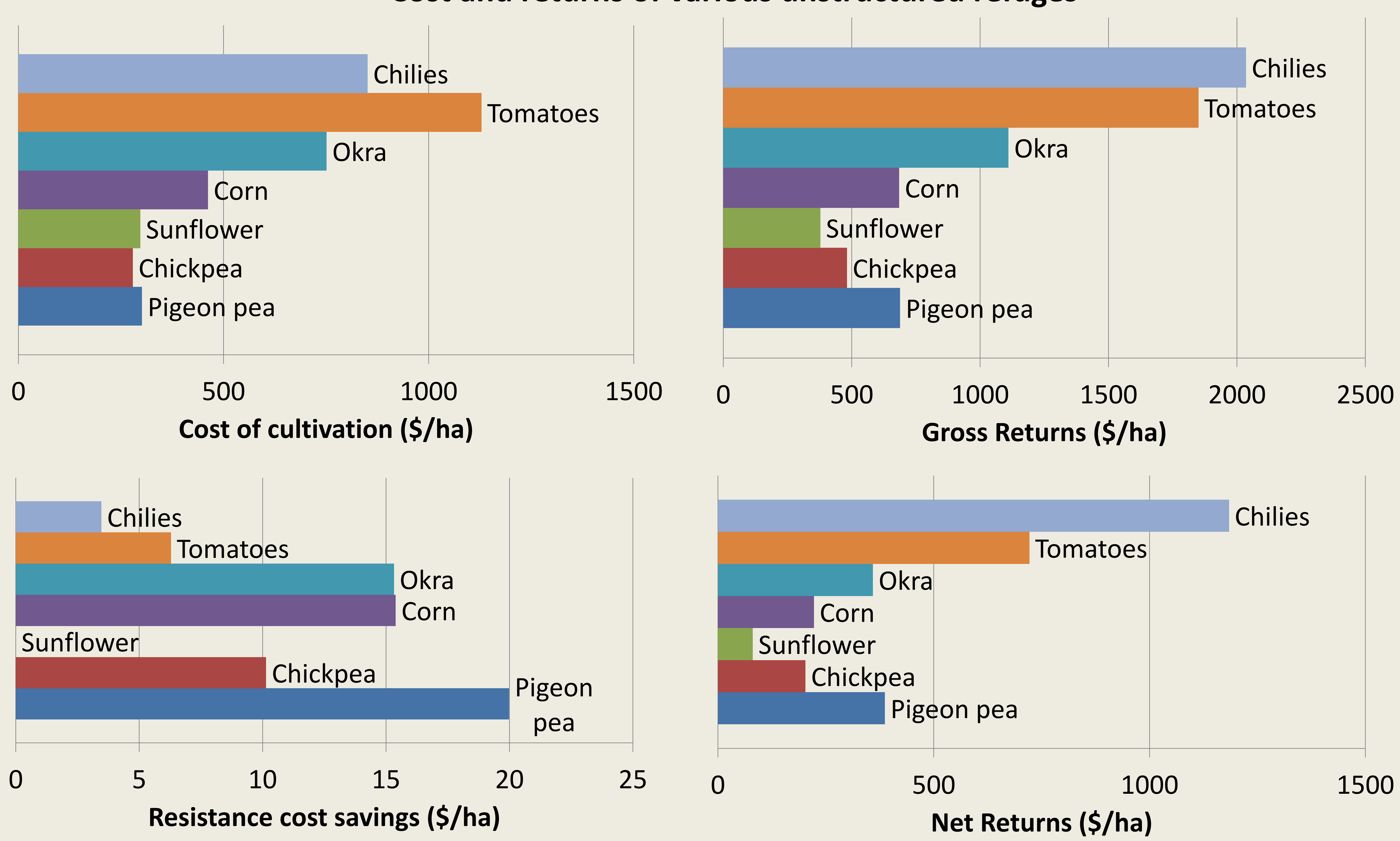
RESULTS

Efficient refuge requirements for each Bt cotton-unstructured refuge combination

Planning Horizons	Pigeon pea		Chickpea		Sunflower		Okra		Tomatoes		Chilies		Corn	
	Refuge	APV[b]	Refuge	APV	Refuge	APV	Refuge	APV	Refuge	APV	Refuge	APV	Refuge	APV
1	0 (0)[a]	824.99	0 (0)	823.65	100 (100)	803.96	0 (0)	826.19	0 (0)	816.41	0 (0)	811.28	0 (0)	824.03
2	0 (0)	824.96	0 (0)	822.54	100 (100)	803.96	0 (0)	825.83	0 (0)	815.78	0 (0)	810.75	0 (0)	823.99
3	0 (0)	824.96	7 (5)	820.51	100 (100)	803.96	0 (0)	825.55	2 (0)	814.50	7 (0)	810.17	0 (0)	823.93
4	0 (0)	824.78	15 (12)	818.77	100 (100)	803.96	0 (0)	824.88	13 (0)	813.48	13 (0)	809.38	0 (0)	823.71
5	0 (0)	824.67	22 (20)	817.53	100 (100)	803.96	3 (0)	823.65	20 (4)	812.53	23 (3)	808.78	0 (0)	823.37
6	0 (0)	824.58	26 (24)	816.51	100 (100)	803.96	10 (0)	822.46	27 (10)	811.86	30 (12)	808.42	0 (0)	822.80
7	0 (0)	824.49	33 (30)	815.76	100 (100)	803.96	12 (6)	821.50	34 (15)	811.34	32 (18)	808.07	2 (1)	821.93
8	0 (0)	824.34	35 (34)	815.12	100 (100)	803.96	19 (10)	820.61	35 (21)	810.92	38 (23)	807.82	6 (4)	820.94
9	0 (0)	824.19	40 (37)	814.56	100 (100)	803.96	21 (14)	819.88	41 (26)	810.54	40 (26)	807.62	11 (10)	820.11
10	0 (0)	823.94	41 (41)	814.10	100 (100)	803.96	26 (16)	819.28	41 (29)	810.25	44 (32)	807.43	17 (13)	819.35

a. Figures in parentheses are efficient refuge requirements when pyrethroid resistance is not considered in the base model.
b. APV values are reported in the US dollars/hectare.

Cost and returns of various unstructured refuges



CONCLUSIONS & IMPLICATIONS

- The unstructured refuges of pigeon pea, corn and okra are relatively more cost effective in delaying resistance and reducing costs of refuges.
- Chilies, Tomatoes and Pigeon pea were found to be the most profitable unstructured refuges that the cotton farmers may plant. The farmers are likely to be better off by planting these crops instead of non-Bt cotton, a structured refuge.
- The study has implications for other developing countries growing Bt crops. For example, Philippines have recently approved the cultivation of Bt corn. Many African countries have significant acreages under Bt cotton. Pakistan has also giving commercial approval to Bt cotton. Also Bt corn is likely to enter India cotton market in the near future. The framework developed by this study will help in evaluating the role of unstructured refuges for Bt crops in these countries.
- The major limitation of this study is that it is not taking into consideration the pesticide use and yield losses (due to bollworm pest) in unstructured refuge crops. Future studies can include information on these parameters to better understand the contribution of unstructured refuges.

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