sustainability

MDPI

Article

Technical Efficiencies and Yield Variability Are Comparable Across Organic and Conventional Farms

Amritbir Riar [1,*], Lokendra S. Mandloi [2], Ramadas Sendhil [3], Randhir S. Poswal [4], Monika M. Messmer [5] and Gurbir S. Bhullar [1]

1 Department of International Cooperation, Research Institute of Organic Agriculture (FiBL), Ackerstrasse 113, CH-5070 Frick, Switzerland; gurbir.bhullar@fibl.org
2 bioRe Research, bioRe Association India, Kasrawad 451228, India; biore.lokendra@gmail.com
3 ICAR-Indian Institute of Wheat and Barley Research (IIWBR), P.O. Box-158, Agrasain Marg, Karnal 132001, India; r.sendhil@gmail.com
4 Division of Agricultural Extension, Indian Council of Agricultural Research (Ministry of Agriculture and Farmers Welfare), Krishi Anusandhan Bhawan-1, Pusa, New-Delhi 110012, India; rsposwal1962@gmail.com
5 Department of Crop Sciences, Research Institute of Organic Agriculture (FiBL), Ackerstrasse 113, CH-5070 Frick, Switzerland; monika.messmer@fibl.org
* Correspondence: amritbir.riar@fibl.org

Received: 11 April 2020; Accepted: 20 May 2020; Published: 22 May 2020

check for updates

Abstract: Cotton is essentially a smallholder crop across tropical countries. Being a major cash crop, it plays a decisive role in the livelihoods of cotton-producing farmers. Both conventional and organic production systems offer alternative yet interesting propositions to cotton farmers. This study was conducted in Nimar valley, a prominent cotton-producing region of central India, with the aim of categorically evaluating the contribution of management and fixed factors to productivity on conventional and organic cotton farms. A study framework was developed considering the fixed factors, which cannot be altered within reasonable limits of time, capacity and resources, e.g., landholding or years of age and/or practice; and management factors, which can be altered/influenced within a reasonable time by training, practice and implementation. Using this framework, a structured survey of conventional and organic farms operating under comparable circumstances was conducted. Landholding and soil types were significant contributors/predictors of yield on organic farms. In contrast, landholding was not the main factor related to yields on conventional farms, which produced the highest yields when led by farmers with more than five years of formal education and living in a joint family. Nitrogen application, the source of irrigation (related to timely and adequate supply), crop rotation and variables related to adequate plant population (seed source, germination rate and plant thinning) were the main management factors limiting cotton yields among conventional and organic farms. Both organic and conventional farms in the Nimar valley exhibited a similar pattern of variation in cotton yields and technical efficiency. This study highlights the enormous scope for improving cotton productivity in the region by improving technical efficiency, strengthening extension services and making appropriate policy interventions.

Keywords: organic cotton; farm management; farm performance; productivity bottlenecks; yield variation; smallholders; capacity development

1. Introduction

India has been a prominent exporter of cotton (*Gossypium* spp.) since ancient times. In 2018, more than 60 per cent of global cotton was produced in five countries—China, India, The United States, Pakistan, and Brazil—among which India accounted for the second largest share of 23%, after

China [1]. India is also the main producer of organic cotton. In 2017–2018, 98% certified organic cotton originated from seven countries—India, China, Kyrgyzstan, Turkey, Tajikistan, the United States and Tanzania—among which India again contributed the largest share of 47% to the global organic cotton production [2].

During the second half of the twentieth century, cultivation practices in India saw dramatic changes. The 'Desi', or indigenous varieties (*Gossypium arboreum*), of cotton were first replaced by American cotton (*Gossypium hirsutum*) varieties and hybrids, and subsequently by genetically modified cotton known as Bt-cotton, as it has genes from *Bacillus thuringiensis* (Bt). Since the year 2002, when genetically modified (GM) cotton was first approved, Bt-cotton has been adopted at an exponential rate, reaching a peak of 90% of the total cotton producing area in 2010 [3]. At the same time, organic cotton production also saw increasing demand, as it offers opportunities for fulfilling sustainable development goals. The global market for organic food and drinks has seen enormous growth from 15 billion USD to 90 billion USD in the past two decades [4,5]. This market trend and the associated changes in consumer preferences have also played a key role in fueling the demand for organic cotton. The sourcing of cotton from production units meeting certain sustainability standards has been on a steep rise for the past decade, of which organic cotton accounts for the largest share, accounting for 70 to 80 per cent of market uptake in actual sourcing and purchasing [6,7]. Global top textile retailers increasingly require certification, which facilitates the increasing demand for certified cotton [7]. As a result, the production area and, correspondingly, the volume of certified cotton has steadily increased from less than 50,000 MT in 2005–2006 to 180,871 MT in 2017–2018 [2]. The impact of organic cotton production on increasing net income remains a complex issue needing further examination; there are, however, other types of economic incentives appealing comparatively clearly to organic farmers, such as cash income and access to credit and inputs [8].

The advantages and disadvantages of organic cotton, as well as genetically modified cotton under conventional production, remain under debate, with the proponents of both systems making contrasting claims [3,9,10]. Although packages of practices for organic and conventional cotton production are entirely different, both systems share the common major factors among the farms, e.g., farm size, irrigation facilities and soil type [11–13]. Theoretically, the major difference between the two systems is management practice. However, there are large yield gaps (realized yield to maximum yield potential) in both the systems, and yield variation is also high between and within the systems [11]. The precise understanding of the major bottlenecks can help to increase the productivity of cotton with the appropriate implementation of research and development efforts. The aim of this study was to identify the bottlenecks influencing the productivity of cotton in relation to agronomic management as well as factors that are beyond the control of farmer in conventional and organic systems.

2. Materials and Methods

2.1. Study Region

Bordered by the Vindhyas mountain range to the North and the Satpura range to the South, Nimar Valley is located in the state of Madhya Pradesh in central India (200–300 m above sea level), and is spread along the Narmada River. In the bottom of the valley, soils are up to several meters deep, dark, rich in clay and of high fertility. The agricultural fields in this part of the valley have a relatively good water supply through numerous irrigation pipelines from the Narmada and some smaller rivers, wells and tube wells. By contrast, the uplands are more heterogeneous due to their undulating profile leading to shallow, light, brownish soils on elevations, but deep, dark, heavy soils in topographic depressions. In the uplands, irrigation water is generally scarce, as there are no river pipelines and only a few channels fed by small dams. Therefore, irrigation water and soil types play an important role in determining the farming practices, as well as in the choice of crops cultivated in rotation with cotton in continued cropping sequence.

Cotton is the major cash crop of Nimar valley. It is grown in rotation with cereals such as wheat (*Triticum aestivum*), maize (*Zea mays*), and sorghum (*Sorghum bicolor*); pulses such as soybean (*Glycine max*), pigeon pea (*Cajanus cajan*), chickpea (*Cicer arietinum*), moong bean (*Phaseolus aureus*); and other food crops such as chilli (*Capsicum annuum*) and onions (*Allium cepa*) [12]. In general, cotton is cultivated as an annual crop with a duration of 150 to 250 days, sown with the first onset of the monsoon (April–June), and the mature bolls are handpicked four or five times, until the plants dry up (September to March). However, under irrigated conditions, cotton is often uprooted at the beginning of December to allow for a second crop (e.g., chickpeas or wheat) in the winter season.

Conventional farmers receive technical advice, to some extent, from the state-run agricultural extension service and suppliers of farm inputs. The recommended N-fertilizer application levels for conventional cotton farming in the region are 100 kg N ha^{-1} for non-Bt cotton, and 120 kg N ha^{-1} for Bt cotton. Besides this, most of the conventional farmers in Nimar valley also apply farmyard manure (FYM) to their fields at the beginning of the cropping period. Since 2003, conventional farmers are increasingly cultivating Bt-cotton hybrids. Seed treatment with synthetic pesticides is recommended. To control sucking pests—and recently also pink bollworm, which has become resistant to Bt-cotton—recommendations are to spray chemical pesticides such as organophosphates, pyrethroids and carbamates 5–15 times per season. To control weeds, farmers are suggested to use synthetic herbicides and growth regulators.

In this study, the term 'organic' refers to certified organic farms, and is interpreted in accordance with the definition by IFOAM. For organic farmers in Nimar valley, the main source of information are the extension services run by the bioRe association, or through social self-learning [11]. The organic cotton farmers are suggested to use balanced nutrient management, including region-specific crop rotation, intercropping with pulses, the recycling of crop residues, and the use of compost and FYM. To complement the nutrient supply, other sources such as de-oiled castor (*Ricinus communis*) cake and powdered rock phosphate are also recommended [14]. Pest management primarily relies on preventive measures, such as selecting robust cotton varieties [15], maintaining a diverse crop rotation, and intercropping with maize and pigeon pea or okra (*Abelmoschus esculentus*) as trap crops. In order to augment the populations of natural enemies, organic farmers are suggested to intercrop flowering plants such as marigold (*Tagetes* spp.) and sunflower (*Helianthus annus*) which attract beneficial insects. In addition, the release of parasitic wasp *Trichogramma* and the application of botanical pesticides prepared from plants that grow locally is highly recommended. The use of pheromone traps to control populations of the pink bollworm (*Pectinophora gossypiella*) is also suggested. In case of strong infestation with bollworms (*Heliothis, Pectinophora and Earias species*), the organic farmers are recommended to use commercially available neem (*Azadirachta indica*) based sprays.

Generally, cotton yields are low and variable in Nimar valley, and often do not reach the attainable level on several farms of the region [11]. This unique social scenario with wide economic disparities, with the existence of contemporary organic and conventional agricultural systems in parallel, offers a rigorous platform for this study to understand the agronomic management and fixed factors that have limited the productivity in the region.

2.2. Farm Survey

During the cotton season of 2015 (May–December), we conducted a survey of organic and conventional cotton-producing farms in the cotton-growing region of West Nimar, India. Using a structured survey tool, 60 organic and 60 conventional farmers from five different cotton-growing areas of West Nimar were interviewed. Each farm was considered as a single operational unit, and the person responsible for decision-making on the farm was interviewed. Farmers to be surveyed were selected randomly, avoiding any selection bias for farm size, education, income or any other demographic factors. To broadly represent the socioeconomic categories of farmers, they were subsequently grouped into small (<2 ha), medium (2–4 ha) and large (>4 ha) farmers according to their landholding, with the smaller-scale farmers recognized as being resource-poor [11,16].

The survey targeted whole-farm agronomic and economic information on cotton crop management practices (including variety selection, fertilizer management, weed and pest management, and number of pickings). In addition, questions related to fixed factors such as land-holding, gender, age, education, family type and farming experience were asked. Farmers were asked to report the cotton yield and agronomic practices of the past three years. Staff members of the bioRe research and extension team personally visited each farm. To derive inferences, regression tree (RT) and technical efficiency (TE) analyses were conducted on this data set

2.3. Regression Tree Analysis

To determine the primary associations between socioeconomic and farm-level factors and productivity, we carried out a regression tree (RT) analysis. RT analysis is a useful tool to explain the dependent variable's (Y-variable) response to a set of independent continuous variables or categorical variables (X-variables), in consideration of fixed and manageable factors. Therefore, the RT approach helps to identify the input factors that are influencing output e.g., productivity. In an RT model, the data is progressively split into subsets in pursuit of increasing homogeneity in the subset. This is represented by a series of 'child nodes' originating from 'parent nodes' of the dependent data (Figures 1 and 2). When all the possibilities of X-variables providing any additional information are exhausted, the process terminates into the end nodes known as 'terminal nodes'. In this study, seed-cotton yield was considered as a Y-variable, and continuous factors (such as farm size, experience and age) and categorical factors (such as education, family type and farming practices) were considered as the X-variables. The X-variables were further divided into fixed and manageable variables, where the former represent the variables which were not under the control of farmer and hard to change, and the latter includes the management related variables, or variables that are easy to modify on willingness. The command used to conduct the analysis was modified from the partitioning option of JMP by using the decision tree method with k-fold cross validation, where k = 10 was used [17].

2.4. Technical Efficiency Estimation by Data Envelopment Analysis (DEA)

Among the different techniques available to estimate the technical efficiency (TE), Data Envelopment Analysis (DEA), a non-parametric optimization model based on linear programming, is widely used owing to its multiple advantages, such as the fact that it does not require parametric specifications, and its lack of imposition on technology, thereby preventing distortion in efficiency measurement [18]. DEA is flexible to multiple inputs-outputs with no prior assumptions. It is an optimization technique to measure the technical efficiency of any decision making unit-DMU (farm/farmer in our case) for a target on the frontier. Eventually, the tool is intended as a performance evaluation method for a DMU in relation to the benchmark (efficient unit). The line that connects the most efficient points is called the 'frontier line', which envelops other data points, and the method is hence popularly known as Data Envelopment Analysis (DEA). The observations to be noted here are as follows [19]:

- The frontier line furnishes the performance of a DMU in relation to an efficient peer(s).
- The efficiency is measured by the deviation of points from the frontier line.
- The efficient frontier serves as a benchmark for the comparison of efficiency.

Theoretically, efficiency can be measured by the two following possible approaches [20]. First, the input-oriented model, which looks for better efficiency by reducing its current input(s) but still producing the same level of output(s). Alternatively, in the output-oriented model, the efficiency can be estimated by increasing its current output(s) using the same input(s) bundle. DEA was initially developed by Charnes et al. [20] from the pioneering work of Farrell [21], proposing a model (CCR:

Charnes, Cooper and Rhodes model) which is input-oriented, with the assumption of constant returns to scale. In the present study, input-oriented DEA has been used, and the functional form is given below:

$$min_{\theta,\lambda}\ \theta$$

$$\text{Subject to}: -y_{it} + Y\lambda \geq 0$$

$$\theta x_{it} - X\lambda \geq 0$$

$$N1' \times \lambda = 1$$

$$\lambda \geq 0$$

where θ is a scalar and an N × 1 vector of constraints. x_{it} and y_{it} are the input and output vectors of the ith farm in tth period, respectively. N is the number of farms for which efficiency has to be worked out. λ is an NT × 1 vector of weights, which defines the linear combination of the peers of the ith farm in the tth period. The value is the input technical efficiency score for the ith DMU, and ranges between 0 and 1. The value of 'one' indicates a point on the frontier, and is hence 100% technically efficient [21]. The deviation of other points from 'one' reflects the level of inefficiency. The DEA has been executed by the data envelopment analysis programme (DEAP) developed by Coelli [22]. In this study, we calculated the technical efficiency for selected inputs (e.g., seed rate and the number of irrigations, N, P and K) related to management factors.

3. Results and Discussion

3.1. Fixed Limiting Factors

Fixed factors are those which could not be altered by the farmer within reasonable limits of time, capacity and resources, e.g., landholding or years of age and/or practice. Regression tree analysis of the fixed factors showed that farming practices were the main factor explaining the yield variation. Organic farming practices were related to lower yield than conventional farming practices (Figure 1, node 1a v 1b). Organic farms with a landholding size of more than 2.83 ha of a single soil type tend to produce higher yields compared to those with more than one type of soil (Figure 1, node 5b v 5a). Smaller organic farms, i.e., with a landholding size of less than 2.83 ha (Figure 1, node 2a) could be further subdivided into three groups based upon landholding as a factor inflicting the cotton yield. Organic farms with landholdings less than 1.42 ha (Figure 1, node 4a) had higher yields, followed by landholdings between 2.43 and 2.83 ha (Figure 1, node 8b), and the lowest yield was from the farms with landholdings between 1.42 and 2.43 ha (Figure 1, node 8a). Contrary to organic farms, landholding was not the main factor related to yields on conventional farms. Conventional farmers with a formal education of above 5 years and living in a joint family had highest cotton yield (Figure 1, node 7b). Experience in farming was the main factor for the farmers who had less than 5 years of formal education: farmers having ≥ 10 years of experience with landholdings of ≥1.42 ha had the lowest yield on conventional farms (Figure 1, node 9a).

These results indicate that the conventional farmers who have received at least a basic school education perform better on their farms. Among the less educated farmers, those who have started farming relatively recently were able to get higher yields from their farms compared to those who had been farming for a longer time. This might contradict the general perception of becoming perfect with the experience; however, this result is very much plausible in the context of the area under study. It is likely that the farmers with more years of farming practice are still following the age-old management practices and technologies, whereas those who started later are more open to new technologies and practices.

It is evident that, for organic farmers, years of practice are not a significant factor, since most of the organic farmers in the survey region converted to organic farming during a comparable time period, and are receiving similar training from bioRe. The results also show that landholding and soil type are the dominant factors influencing yields on organic farms. The finding that the organic farms that are either larger than 2.83 ha or smaller than 1.42 ha produce higher yields compared to mid-sized organic farms seems to be linked to the availability of resources for farm operations. It is likely that the larger farms have better access to resources, e.g., the use of farm machinery, and are capable of attaining higher resource use efficiencies by the principle of economy of scale. The small farmers largely depend on family labor for farm operations and are able to adequately perform various farm operations themselves. Whereas, for mid-sized farms, the family labor is probably insufficient to perform all the operations in an adequate or timely manner, and the economy of size has limited scope for the efficient utilization of resources such as mechanization or hired manual labor. It is also noticeable that the yields on larger organic farms with a single soil type were higher than those with mixed soil types. One reason is that the majority of the farms with a single soil type have heavy vertisols, which are much more fertile than light sandy soils. Secondly, having limited training, the farmers could better manage their crops if they have to perform one type of practice on their fields, rather than the case where they have to select different practices for different fields. For example, a high yielding variety recommended for cultivation on heavy soils may not be suited for light soils, and, further, the optimal plant density and crop management practices would differ substantially. Yet, a farmer with limited training and knowledge might be tempted to grow a very high yielding variety in both the situations following similar practices, leading to yield losses. This kind of bottleneck could be resolved by training farmers on the importance of implementing soil type specific cultivars, plant density and management practices.

3.2. Management Factors

Management factors comprise of those factors that could be altered/influenced within a reasonable time by training, practice and implementation. This section sheds light on the management factors that significantly hinder cotton crop yield on both organic and conventional farms. The decision tree of management practices showed that nitrogen application, source of irrigation (related to timely and adequate supply), crop rotation and variables related to adequate plant population (seed source, germination rate and plant thinning) were the main factors limiting cotton yield in Nimar valley (Figure 2).

Nitrogen, combined with a source of irrigation, was the most important limiting factor for cotton yield. The highest cotton yield was achieved by applying $\geq$133 kg N ha^{-1} with assured irrigation from a combination of river and pumps (Figure 2, node 3b). For other farms with only one source of irrigation (river/well/pump), or any combination that did not include a river and pump combination, higher yield was achieved with $\geq$10 irrigations during the cotton growing season, compared to farms which provided <10 irrigations to the cotton crop (Node 6b vs. 6a). This showed that the source and quantity of water for irrigation co-limit cotton yield. On farms with the capacity for <10 irrigations for the cotton crop, the yield was lower if the preceding crop was wheat, compared to the cases where there was only one crop harvested per year (Node 8a vs. 8b). The cultivation of a single cotton crop per year gave a higher yield if more than one source of irrigation was available, rather than if a well was the only source of irrigation (Node 11b v. 11a). Cotton crops after wheat gave a higher yield when thinning operations were performed, compared to the cases with no thinning (Node 10b v. 10a).

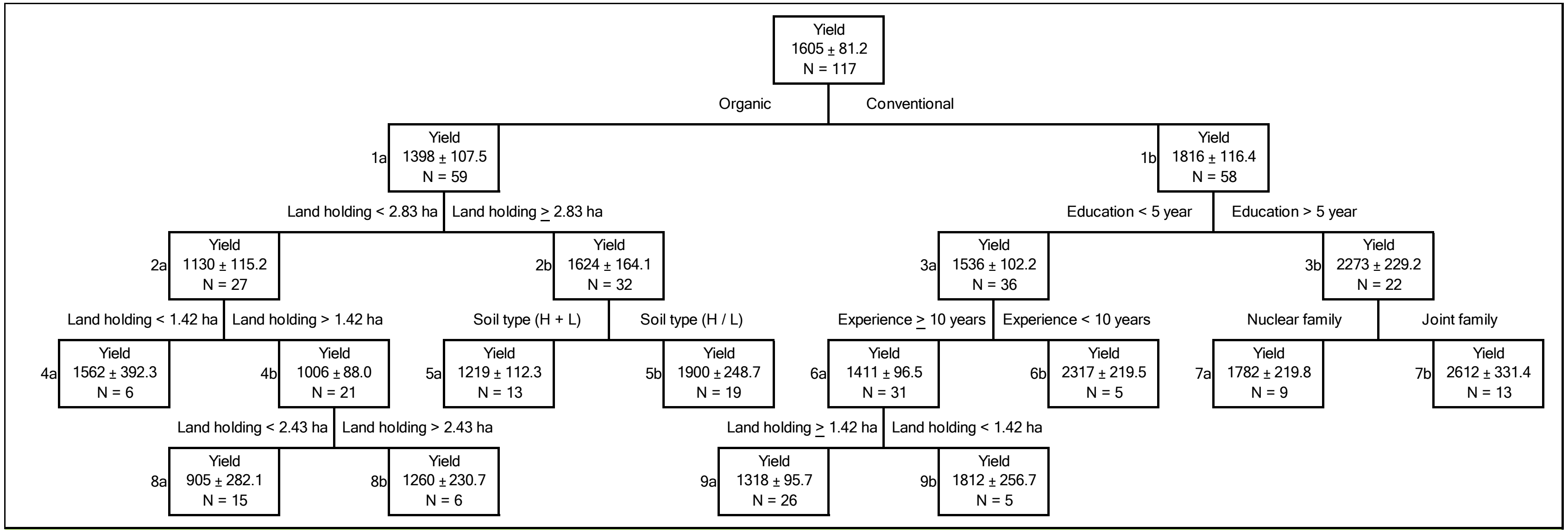

Figure 1. Regression tree predicting seed cotton yield from fixed factors including farming practices, landholding, soil type, gender, age, education, farming experience and family type.

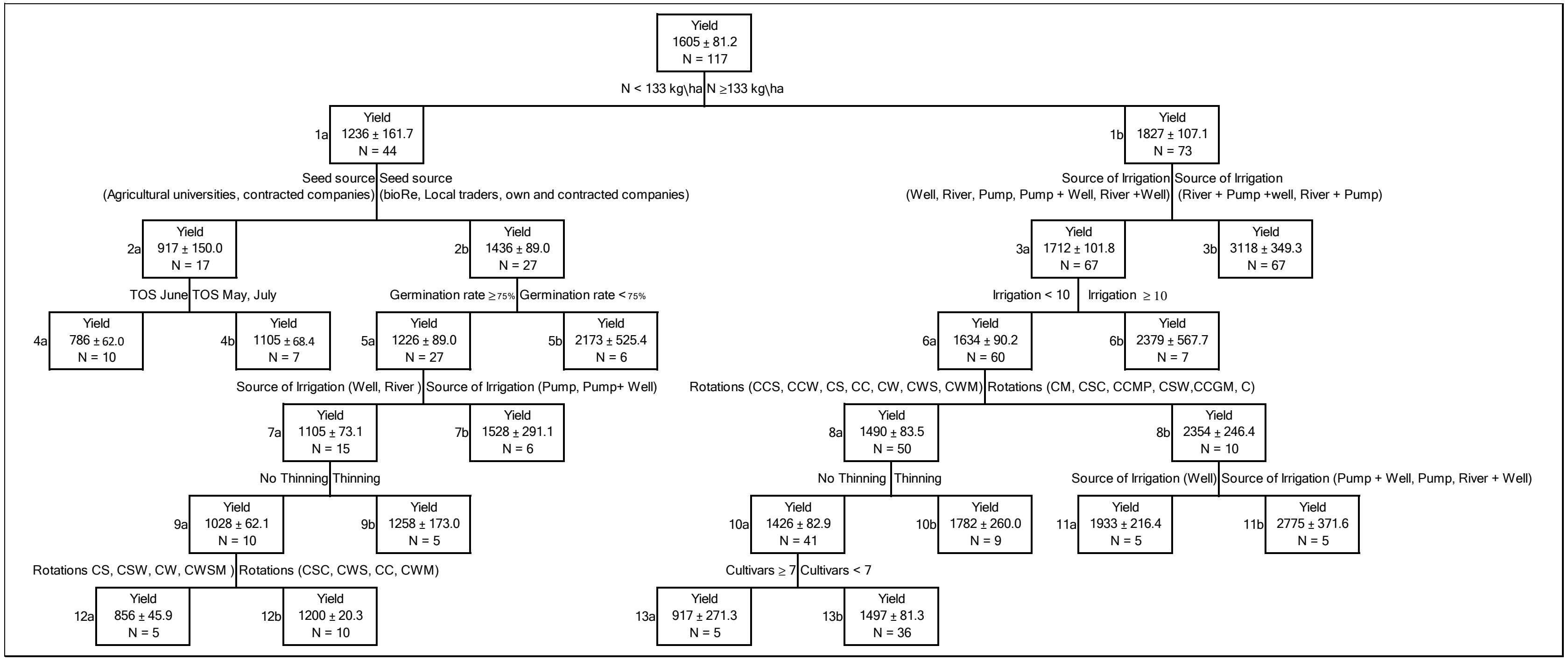

Figure 2. Regression tree depicting the variation in seed cotton yield from different farms, as influenced by management factors (including irrigation, rotations, number of cultivars, seed source, time of sowing, seed rate, seeds per hole, thinning practice, germination rate, nitrogen inputs, method of irrigation, and number and source of irrigations).

The farms obtaining the lowest cotton yields applied <133 kg N ha^{-1}, sourcing seed from agricultural universities or contract companies and sowing the cotton crop in the month of June (Figure 2, node 4a). Within the lower N-application (<133 kg N ha-1) group, the farms that relied on bioRe or local traders, or their own seed and contract companies as a seed source, obtained higher yields (Node 2a). This sub-grouping largely represents the organic farms associated with bioRe. The next level factor for the farms with seed supply from bioRe, local traders, or their own and contract companies' seed, was the germination percentage (Node 5a & b). Interestingly, the farmers who reported germination rates of lower than 75% attained higher yields compared to those reporting ≥75% germination (Node 5b v. 5a). This reflects the fact that the farmers who were more aware of lower germination on their farms were the ones opting for gap filling, thereby maintaining the plant stand on their fields. On the contrary, the farmers who perceived the germination of their crops to be good enough did not resort to any efforts to maintain sufficient plant stand and therefore got lower yields. The farmers reporting higher germination rate (≥75%) got relatively higher yields when they had assured irrigation sourced from pump (tube well) or pump and well, compared to the farmers who had only well or river as the sole irrigation source (7b vs. 7a). In the absence of assured irrigation (i.e., no water pump) higher yields could be obtained when plant thinning operations were performed (Node 9b v. 9a). Interestingly, farmers following some of the crop rotations could obtain higher yields of cotton even without thinning, compared to those following some other crop rotations. The reasons for such differences could not be established in the absence of detailed agronomic data. It could probably be related to the N supply to the cotton crop, since some rotations could be more N demanding, thereby leaving a very limited residual N supply for cotton, leading to poor cotton yields and the need for further studies.

The results of this analysis (Figure 2) identify N supply as the major limiting factor to achieve higher cotton yields. Cultural practices aimed at good crop management, such as timely irrigation, careful crop rotation choice and cultural operations to achieve optimum plant population (e.g., plant spacing, thinning and gap filling) could significantly improve yields of the underperforming farms. The appropriate management practices could particularly play a crucial role in increasing yields on the organic farms with relatively limited scope of substantially increasing N supply due to reliance on locally available organic sources. These results emphasize the strong need for farmers' training for the appropriate implementation of existing technologies.

3.3. Cotton Yield and Technical Efficiency

A number of factors were found to influence cotton productivity, agronomic management practices being the most important ones. Among the fixed factors, farm size, irrigation facilities and soil type influence the decision-making, as well as the effectiveness of crop management practices. For instance, the water and nutrient supply to a crop could be limited by soil type and the irrigation facilities available. In this study, cotton yield was found to be significantly influenced by farming practices, while the effect of farm size was insignificant, except that conventional larger farms were statistically higher yielding compared to small-sized organic farms (Table 1).

In order to identify limiting factors, we calculated the technical efficiency, selecting the prominent management factors based upon RT analysis (seed rate, irrigation and nutrients (NPK)). Technical efficiency indicates the capability of a farm (or farmer) to produce the maximum possible physical output(s), i.e., the potential level with the given bundle of resources and input services, along with the production technology. The efficient farmers/farms (benchmark units) decide the production possibility curve and the rest will lie below them, indicating the level of inefficiency in comparison to the benchmarks. The technical efficiency of surveyed farms did not differ significantly for farming practices or farm size (Table 1). The analysis of three key factors (seed rate, irrigation and nutrient inputs) showed a substantial range of variation among the farms for cotton yield and TE. Conventional farms in the region were operating with a technical efficiency of 60%, compared to 54% of organic farms, indicating that both farming systems were not using all the available resources efficiently. In each category, some farms operated at a relatively high TE and a correspondingly higher productivity. Substantial variation in cotton yield and TE among the studied farms indicates that improving individual management of the farm/cotton crops could be the first step to increase yields.

Table 1. Comparison of mean seed cotton yield and technical efficiency from different soil types in conventional and organic farming systems according to different farm sizes in west Nimar. Means marked with same letter do not differed significantly. Small letters represent analysis within farming systems and capital letters compare conventional and organic farming systems.

Farming Practice	Farm Size (n)	Cotton Yield (Log) ± s.e. kg ha^{-1}	Technical Efficiency (Log) ± s.e. %
Conventional	Large >4 ha (14)	2071 ± 238 (7.53 ± 0.14) ^{a}	73.2 ± 6.7 (4.22 ± 0.12) ^{a}
	Medium 2–4 ha (18)	1455 ± 152 (7.18 ± 0.11) ^{ab}	51.9 ± 5.1 (3.87 ± 0.10) ^{a}
	Small <2 ha (8)	1953 ± 356 (7.49 ± 0.15) ^{ab}	55.9 ± 7.6 (3.96 ± 0.13) ^{a}
Mean		1770 ± 133 (7.40 ± 0.13) ^{A}	60.0 ± 3.8 (4.02 ± 0.12) ^{A}
Organic	Large >4 ha (9)	1267 ± 126 (7.11 ± 0.10) ^{ab}	48.2 ± 5.2 (3.82 ± 0.12) ^{a}
	Medium 2–4 ha (20)	1419 ± 191 (7.13 ± 0.11)^{ab}	59.8 ± 6.0 (3.99 ± 0.11) ^{a}
	Small <2 ha (5)	935 ± 135 (6.79 ± 0.16) ^{b}	42.5 ± 5.1 (3.71 ± 0.14) ^{a}
Mean		1370 ± 121(7.01 ± 0.12) ^{B}	54.2 ± 4.0 (3.84 ± 0.12) ^{A}

4. Conclusions

A similar pattern of variation in cotton yields and TE was noticed between conventional and organic farms in the Nimar valley. The study highlighted the enormous potential to improve cotton productivity. A significant productivity increase could potentially be achieved by supporting underperforming farms, even to the average level. Interventions can be made at different levels to address the needs of farmers for different farming practices, e.g., training on how to manage different soil types could increase the yield by 55% on organic farms, or choosing the right crop rotation could lead to a 60% higher yield on some farms. With our experience of over twelve years of working with cotton farmers in the region, in some cases we observed that lower yields were also associated with farmers' (particularly the smallholders) unawareness of the potential of increasing yields with available technologies. Some of the yield variations could be addressed by improved agronomic management; for example, maintaining plant population by thinning and gap filling, early sowing (May) and improving irrigation supply. In view of the above conclusions, for the integrity and sustainability of organic cotton in the Nimar valley of India, we make the following recommendations:

1. The capacities of extension services need to be enhanced with appropriate training aimed at bridging the knowledge gap on the optimal use of resources, along with sustainable farming practices.
2. The awareness of particularly low producing farmers, of the scope of increasing yields and the potential of existing technologies (improving technical efficiency), needs to be enhanced. Demonstrations of gaps and variations of cotton productivity among the farms, as well as peer to peer learning from better performing farmers, could prove effective.
3. Involving farmers and other relevant local stakeholders in the process of technology development, e.g., by using participatory research approaches, will speed up the adoption rate and leverage the efforts to overcome the gap in technical efficiencies across farms.

Author Contributions: A.R. and G.S.B. designed the study; L.S.M. and A.R. coordinated the data collection; A.R. and R.S. analyzed the data; A.R. and G.S.B. prepared the first draft of the manuscript; M.M.M. and R.S.P. supported the design and analysis; all authors revised the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This work was financially supported by the Biovision Foundation, Coop Sustainability Fund, Liechtenstein Development Service (LED) and the Swiss Agency for Development and Cooperation (SDC).

Acknowledgments: We thank bioRe India Ltd. for their sustained support of the participating farmers. We also thank the students and field staff who contributed to this work from time to time. Above all, we sincerely acknowledge and appreciate the cooperation of the cotton farmers of Nimar valley.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. FAOSTAT. Production of Cotton by Countries. UN Food & Agriculture Organization. 2020. Available online: http://faostat.fao.org/site/339/default.aspx (accessed on 30 March 2020).
2. Barsley, L.; Bettany, P.; Santos, A.D.; Gosai, A.; Tan, E.; Truscott, L. Organic Cotton Market Report 2019: Covering production trends and initiative updates from the 2017/18 harvest year. Available online: https://store.textileexchange.org/product/2019-organic-cotton-market-report/ (accessed on 15 May 2020).
3. Kranthi, K.; Stone, G.D. Long-term impacts of Bt cotton in India. *Nat. Plants* **2020**, *6*, 188–196. [CrossRef] [PubMed]
4. Willer, H.; Lernoud, J. The World of Organic Agriculture. Statistics and Emerging Trends 2019. Available online: https://shop.fibl.org/chen/mwdownloads/download/link/id/1202 (accessed on 15 May 2020).
5. Duijn, H.V.; Maas, M. Organic Cotton's Threshold Moment: The Organic Cotton Accelerator. Available online: https://www.semanticscholar.org/paper/Organic-Cotton-%E2%80%99-s-Threshold-Moment-%3A-The-Organic-Duijn-Maas/43380885dc7a67c63dab5e0cfbf397b691edaf12 (accessed on 15 May 2020).
6. Ferrign, S. Mind the Gap: Towards a More Sustainable Cotton Market. Available online: https://www.solidaridadnetwork.org/sites/solidaridadnetwork.org/files/publications/Mind%20the%20Gap%20-%20Towards%20a%20more%20Sustainable%20Cotton%20Market.pdf (accessed on 25 March 2020).
7. Heuvels, S.; Molenaar, J.W.; Raap, N.; Petit, C. Sustainable Cotton Ranking 2017. Available online: http://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/Report_Sustainable_Cotton_Ranking_2017.pdf (accessed on 9 November 2019).
8. ICAC Expert Panel. Measuring Sustainability in Cotton Farming Systems—Towards a Guidance Framework. Available online: http://www.fao.org/3/a-i4170e.pdf (accessed on 20 March 2020).
9. Gutierrez, A.P.; Ponti, L.; Herren, H.R.; Baumgärtner, J.; Kenmore, P.E. Deconstructing Indian cotton: Weather, yields, and suicides. *Environ. Sci. Eur.* **2015**, *27*, 12. [CrossRef]
10. Stone, G.D. Constructing facts: By cotton narratives in India. *Econ. Political Wkly.* **2012**, *47*, 62–70.
11. Riar, A.; Mandloi, L.S.; Poswal, R.S.; Messmer, M.M.; Bhullar, G.S. A diagnosis of biophysical and socio-economic factors influencing farmers' choice to adopt organic or conventional farming systems for cotton production. *Front. Plant Sci.* **2017**, *8*, 1289. [CrossRef] [PubMed]
12. Eyhorn, F.; Ramakrishnan, M.; Mäder, P. The viability of cotton-based organic farming systems in India. *Int. J. Agric. Sustain.* **2007**, *5*, 25–38. [CrossRef]
13. Eyhorn, F. *Organic Farming for Sustainable Livelihoods in Developing Countries? The Case of Cotton in India*; vdf Hochschulverlag AG: Zürich, Switzerland, 2007.
14. Cicek, H.; Bhullar, G.S.; Mandloi, L.S.; Andres, C.; Riar, A.S. Partial acidulation of rock phosphate for increased productivity in organic and smallholder farming. *Sustainability* **2020**, *12*, 607. [CrossRef]
15. Vonzun, S.; Messmer, M.M.; Boller, T.; Shrivas, Y.; Patil, S.S.; Riar, A. Extent of bollworm and sucking pest damage on modern and traditional cotton species and potential for breeding in organic cotton. *Sustainability* **2019**, *11*, 6353. [CrossRef]
16. Coventry, D.; Poswal, R.; Yadav, A.; Riar, A.S.; Zhou, Y.; Kumar, A.; Chand, R.; Chhokar, R.; Sharma, R.; Yadav, V. A comparison of farming practices and performance for wheat production in Haryana, India. *Agric. Syst.* **2015**, *137*, 139–153. [CrossRef]
17. Goupy, J.; Creighton, L. *Introduction to Design of Experiments with JMP Examples*; SAS publishing: Cary, NC, USA, 2007.
18. Mahida, D.; Sendhil, R.; Sirohi, S.C.B.; Chandel, B.S.; Ponnusamy, K.; Sankhala, G. Technical efficiency of cooperative member vis-à-vis nonmember dairy farms in Gujarat–application of data envelopment analysis. *Indian J. Econ. Dev.* **2018**, *6*, 1–9.

19. Chandrasekar, V.; Sendhil, R.; Ramasundaram, P. *Data Envelopment Analysis, e-Compendium on Data Analysis Tools and Approaches (DATA) in Agricultural Sciences*; Indian Institute of Wheat and Barley Research (IIWBR): Karnal, Haryana, India, 2017; pp. 82–86.
20. Charnes, A.; Cooper, W.W.; Rhodes, E. Measuring the efficiency of decision making units. *Eur. J. Oper. Res.* **1978**, *2*, 429–444. [CrossRef]
21. Farrell, M.J. The measurement of productive efficiency. *J. R. Stat. Soc. Ser. A* **1957**, *120*, 253–281. [CrossRef]
22. Coelli, T. *A Guide to DEAP Version 2.1: A Data Envelopment Analysis (Computer) Program*; Centre for Efficiency and Productivity Analysis, University of New England: Armidale, Australia, 1996; Volume 96.