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A Meta-Analysis of the Use of Genetically Modified Cotton and Its Conventional in Agronomy Aspect and Economic Merits

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ABSTRACT
Rising the area of growing Genetically Modified (GM) cotton mostly derived from the yield gain and income gain both GM cotton and conventional cotton is affected by seed cost, pesticide cost, management and labor cost. Therefore, planting GM cotton should be considering both agronomy aspect in yield gain and economic dimension in income gain. Those aspects are not only for GM cotton but also for conventional cotton. This paper is a meta-analysis as a synthesis of current research by searching literature both peer-reviewed and non peer-reviewed. A meta-analysis depicted that individual study mostly favor GM cotton in yield gain, seed cost and pesticide cost. However, in terms of pesticide cost a meta-analysis prone to favor non GM cotton. Moreover, a meta-analysis revealed that the positive impact in the differences of GM cotton and conventional cotton as the evidence of the publication is highly significant.
Key Words : Genetically Modified, Cotton, Conventional, Yield, Income, Gain, Meta-Analysis

1. INTRODUCTION

Genetically Modified (GM) crop are crop derived from genetically modified organism which is expressing Cry toxins derived from *Bacillus thuringiensis* (Bt) have been planted worldwide, and are effective tool for pest control (Yu, et al., 2011). The genetic modification of cotton (*Gossypium hirsutum*) for insect resistance to the bollworm complex (Lepidoptera) is being heralded as a highly beneficial application of agricultural GM technology (Morse, et al., 2005). Bt genes (*Cry1Ac, Cry1Ab, Cry2Ab and Cry1F)* of cotton were commercialized in 11 countries in 2009 (James, 2010).

Numerous studies on Bt cotton in developing countries claim that its use brings benefits to smallholders because it decrease the number of pesticide sprayings and increased yields (Zhao, et al., 2011). According to Kaphengst, T. et al., (2010) stated that there is substantial evidence that the adoption of Bt cotton provides economic benefits for farmers in a number of countries. Carpenter (2010) reveals that covers 12 countries worldwide and summaries results from 49 peer-reviewed publications based on report on farmers surveys comparing yields and other indicators of economic performance for adopters and non adopters of being commercialized GM crops indicated that benefits from growing GM crops mainly derive from increases yields, which are greatest for small scale farmers in developing countries insofar as they have benefitted from the spillover of technologies originally targeted at farmers in industrialized countries.

The objectives of this paper is to use data based on refereed journals both peer reviewed and non-peer reviewed through online searches from long term studies to provide an understanding of the effects of long term used of transgenic cotton for economic benefits of smallholder farmers through meta-analysis. Started on the evidence of widespread use of transgenic cotton both in developed countries such as USA and Australia and developing countries such as China and India. This will identify some economic parameters which has used based on the research methodology of a wide range data in survey, and field trials in the scale farm.

2. MATERIALS AND METHODS

We focused on agronomy merits and economic indicators which can affect directly to farmers' income, such as crop yields, seed costs, pesticide and herbicide costs, and labor costs which refers to the economic costs and benefits for farmers growing Bt cotton compare to the its counterparts. Moreover, in order to consider most of the available data and to obtain an overall understanding of economic performance, comparative study conducted at different geographic levels, including field trials, farm level survey and general reviews publication both in international and national level. In addition to peer-reviewed publication, data from governmental reports and statistics, also conference proceedings as well as other sources were subsumed in this study.

Meta-analysis is a statistical techniques for combining the finding from independent studies. In this analysis data from individual studies may be pooled quantitatively and reanalyzed using established statistical methods. Meta-analysis if trials provides a precise estimate of treatment effect, giving due weight to the size of the different studies included. The rationale for meta analysis is that, by combining the sample of individual studies of the treatment of GM cotton and non GM cotton, the overall sample size is increased, thereby improving the statistical power of the analysis as well as the precision of the estimates of treatment effect by using GM cotton and its conventional. In this study we applied STATA 12.1 as the statistical tool to analyze the meta data based on the database set. We should note that, in meta analysis, data from the individual studies are not simply combined, as if they were from a single study. Results in this study provides the information that some of the single studies either GM cotton effect or non GM cotton effect is likely to be closer to the true effect that we are trying to estimate.

There are two statistical models in meta-analysis, viz. the Fixed Effect Model and the Mixed or Random Effect Model. A fixed effects model assumes a normal distribution, a single true effect size in the population, and variation across studies due to sampling error only. The random effects model assumes that effect size across studies and provides a method to estimate the average effect size (Borenstein et al., 2009). In our study this would be assumed that factors or economic indicators vary from region to region across countries or may have changed over time. A major drawback of this model, however, is that there is no way to control for heterogeneity. By using a mixed model (both fixed and random effects), we get the advantages of the random effects model, but also gain a method for controlling heterogeneity (Cooper and Hedges, 1994; Rosenberg et al., 2000; Borenstein et al., 2009).

The significance of the residual heterogeneity, τ^2, was tested in each meta analysis. The metan command, by default, will calculate the Q test for the heterogeneity and I^2 to assess the degree of heterogeneity. Metan now displays the I^2 statistic as well as Cochran's Q to quantify heterogeneity, based on the work by Higgins and Thompson (2004) and Higgins et al. (2003). Briefly, I^2 is the percentage of variation attributable to heterogeneity and is easily interpretable. Cochran's Q can suffer from low power when the number of studies is low or excessive power when the number of studies is large.

The absence of heterogeneity is usually tested using Q (Cochran, 1954), which under a fixed effects Ho ($\tau^2 = 0$) is given as the weighted sum of squared differences between individual mixing effects and the meta-effect. For comparability reasons, Q may be better reported as the percentage of variation across effect sizes that is due to the heterogeneity rather than chance (Higgins and Thompsons, 2002; Higgins et al., 2003), having I^2 is calculated from the results of the meta-analysis by :

$$I^2 = 100\% \times \frac{(Q - df)}{Q} \qquad (1)$$

where Q is Cochran's heterogeneity statistic and df is the degrees of freedom. Negative values of I^2 are set to zero so that I^2 lies between 0% and 100%. A value of 0% indicates no observed heterogeneity, and larger values show increasing heterogeneity. Although there can be no absolute rule for when heterogeneity becomes important, Higgins et al. (2003) tentatively suggest adjectives of low for I^2 values between 25%–50%, moderate for 50%–75%, and high for ≥75%. Empirical Bayes variables are estimates of effect and standard errors for each study that take into account within and between study variance.

In contrast to Q, I^2 can be directly compared between meta-analysis with different number of studies and different combinations of covariate, and it was thus used to quantity the importance of introducing a covariate or a factor to a meta-regression model (Lars et al., 2009). Therefore, the I^2 is effectively the percentage of variance explained by heterogeneity, and measures whether the observed variance is greater than would be expected by chance. Our general interpretation of heterogeneity is that I^2 of 50 or less is desirable. An I^2 value between 50 and 75 is interpreted as likely measuring a single latent variable, but needs to be standardized. I^2 values over 75 are addressed individually (Adam et al., 2009).

3. RESULTS AND DISCUSSION

Meta-analysis is a two stage process (Deeks JJ, et al. 2001). The first stage is involves the calculation of a measure of treatment effect with its 95% Confidence Interval (CI) for each individual study. The summary statistics that are usually used to measure treatment effect of odds ratio (OR).

In the second stage of meta analysis, an overall treatment effects is calculated as a weighted average of the individual summary statistic. We should note that, in meta analysis, data from the individual studies are not simply combined as if they were from single study. Greater weights are given to the results from studies that provide more information, because they are likely to be close to the "true effect" we are trying to estimate. The weights are often the inverse of the variance (the square of the standard error) of the treatment effect, which relates closely to sample size. In this case, the treatment effect is the impact of using GM cotton and the control is non GM cotton.

3.1. Yield Gain

In this study, we provided the meta-analysis of yield gain from 46 studies of systematic review. We noted that there is a strong evidence of the heterogeneity studies by analyzing fixed effect and random effect estimation. Table 1 reflects fixed and random effects pooled estimates, lower and upper 95% confidence limits, and asymptotic z-test for null hypothesis that true effect (unbiased effects) = 0. Test for heterogeneity: Q= 1611.913 on 45 degrees of freedom (p= 0.000). Random-effect Der Simonian and Laird estimate of between studies variance = 0.038 (τ^2). $I^2 = 97.2\%$. Q > df indicated that the observed variation greater than we would expect based on within-study error (Borenstein et al. 2009).

Figure 1 shows, at a glance, information from the individual studies that went into the meta analysis, and an estimate of the overall results. It is also allows a visual assessment of the amount of variation between the results of the studies. This is (Figure 1) is adapted from systematic review and meta analysis which examined the yield gain of GM cotton compared with non GM cotton. All results on the left hand side are in favor of the GM cotton implementation, those on the right hand side in favor of the use of non GM cotton. Figure shows that most of the studies are favor the implementation of GM cotton and it is notable that if the 95% confidence interval does not overlap the *y*-axis, that is the result is statistically significant, as 95% of the result are expected to lie one side. In this case there are 15 studies which are not statistically significant.

The shape of the diamond in the last row of the graph illustrates the overall result of the meta-analysis. The middle of the diamond sits on the value for the overall effect of estimate and the width of the diamond depicts the width of the overall confidence interval. If the diamond does not cross the "line of no effect", the calculated difference between the yield gain of the use of GM cotton and its conventional can be considered as statistically significant. In this case, figure above noted that overall of those studies are statistically significant even are not highly significant. Statistical significance of the overall result in this study is also expressed with the probability value (*p* value) in the 'test for overall effect'. Commonly, the result is regarded as statistically significant if $p < 0.05$ (Ried, 2006). In this case *p* value can be seen at Table 1 that indicated statistically significant for the overall of the studies. I^2 value of 97.2% indicates that the higher the value the more the heterogeneity increased.

The black squares symbol represent the odds ratio of the individual studies and the area of the black squares reflects the weight each trial contributes in the meta analysis. The bigger the box, the more influence the study has on the overall results. The influence or 'weight' of study on the overall results is determined by the study's sample size and the precision of the study results provided as a confidence interval. In general, the bigger the sample size and the narrower the confidence interval, the greater the weight of the study.

3.2. Seed Response

This shows the result of meta analysis in terms of pesticide, table below describes the fixed and random method for examined 25 studies. Fixed and random effects pooled estimates, lower and upper 95% confidence limits, and asymptotic z-test for null hypothesis that true effect = 0. Test for heterogeneity: Q= 110.823 on 24 degrees of freedom (p= 0.000). Random-effect Der Simonian and Laird estimate of between studies variance = 0.171 (τ^2). $I^2 = 78.34\%$.

Statistical significance of the overall result in this study is also expressed with the probability value (*p* value) in the 'test for overall effect'. Table 2 expressed that all the studies both fixed method and random method are statistically significant. Furthermore based on the figure 2, the most of the 95% confidence interval does not overlap the *y*-axis, therefore the result is statistically significant. In this study only Sun (2000), Pray (2001), Pray (2002), Huang (2003), and Gaurav (2012) are not statistically significant. This is because their confidence interval overlaps the *y* axis. I^2 value of 78.34% indicates that the data show increasing heterogeneity.

Figure 2 reflects that overall the horizontal line (whiskers) explain that the longer the line, the wider the confidence interval, the less precise the study results. In the other words, most of those studies are not statistically significant. The box square represent the odds ratio of the individual studies and the area of the black square reflects the weight each trial contributes in the meta analysis (Akobeng, 2005). The higher the percentage weight, the bigger the box, the more influence the study has on the overall results. It means that the implementation of the GM cotton seed is statistically significant based on the individual study. In the other word, we believe that those studies have the true effect. In addition, we can see at figure 2 that symbol of the diamond is the left hand side of 'the line of no effect'. It means that those studies not need to the more episode by using GM cotton seed (fewer episodes).

3.3. Pesticide Response

Twenty eight studies have been analyzed by meta-analysis and have been pooled as the estimate on of the

effect of the studies. Table 3 describes the statistical analysis by using two different methods. This analysis resulting in fixed and random effects pooled estimates, lower and upper 95% confidence limits, and asymptotic z-test for null hypothesis that true effect = 0. Test for heterogeneity: Q= 3764.723 on 27 degrees of freedom (p= 0.000). Random-effect Der Simonian and Laird estimate of between studies variance = 1.955 (τ^2). I^2 = 99.28% which indicates the higher the value of I^2 the more the heterogeneity increased. We can see from the Table 3 that both fixed and random methods are statistically significant with p value < 0.05. It means that overall results are statistically significant with 28 individual studies of pesticide cost of using GM and non GM cotton.
Surprisingly, Figure 3 expressed that overall studies favor on the right hand side which means that those studies prefer to the use of pesticide of the non GM cotton. Furthermore, all the studies show the significance of the 95% confidence interval based on the meta data. Hoque (2000), Pyke (2000), Doyle (2002), and Fitt (2003) show that these studies influence the result of the use of pesticide (pesticide cost) of non GM cotton which is determined by the study's sample size. In addition, this study shows that the shape of the diamond is the right hand side of 'the line of no effect'. In the other words, more experiments are needed in the treatment group (the use of chemical spray of non GM cotton). In figure 3, the diamond shape does not touch the line of no effect (that is, the confidence interval of the odds ratio does not include 1) and this means that the difference found between the expenditure of chemical spray of GM cotton and its conventional was statistically significant.

3.4. Management and labor Response

Table 4 depicts the study results of 20 studies of management and labor cost based on the meta data. We can see that p value of fixed method lower than 0.005, this means that overall studies are statistically significant under the fixed method. In contrast, those studies are not statistically significant by using random effect method which p value < 0.05. Fixed and random effects pooled estimates, lower and upper 95% confidence limits, and asymptotic z-test for null hypothesis that true effect = 0. Test for heterogeneity: Q= 673.405 on 19 degrees of freedom (p= 0.000). Random-effect Der Simonian and Laird estimate of between studies variance = 0.124 (τ^2). Test for heterogeneity shows that I^2 = 97.17% which indicates increasingly heterogeneity.
In this study (Figure 4), we noted that some studies (8 studies) favor for the non GM cotton (control group) and the remaining studies (12 studies) favor for the GM cotton. This means, both control and treatment group have almost the same effect size based on the meta data study. In addition, some of the studies are not statistically significant (7 studies). Furthermore, the diamond shape is the left hand side of the line of no effect (that is overall studies results are statistically significant) and this means that those studies has no effect between GM cotton and its counterpart in terms of the management and labor cost.

3.5. Net Revenue Response

There were twenty five studies which have been analyzed by fixed effect size and random effect size. Overall studies show that p value lower than 0.05 (0.000), this means those studies is statistically significant both in fixed effect size and random effect size. Fixed and random effects pooled estimates, lower and upper 95% confidence limits, and asymptotic z-test for null hypothesis that true effect = 0. Test for heterogeneity: Q= 1828.069 on 24 degrees of freedom (p= 0.000). Random-effect Der Simonian and Laird estimate of between studies variance = 0.219 (τ^2). I^2 = 98.28%. This indicates the higher the value the more heterogeneity increased. Figure 5 express the forest plot based on the meta data analysis. We can see that most of the studies favor the GM cotton in terms of net revenue. A little favor the non GM cotton. The plot shows, at glance, the information for each individual studies about net revenue which is statistically significant in 95% confidence interval. A typical forest plot in figure above shows that the shape of diamond is the left hand of the line no effect, this means that the difference found between the two groups (GM cotton and non GM cotton) in terms of net revenue was statistically significant. The significance of the 95% confidence interval would contain the true underlying effect in 95% of the occasion if the study repeated again and again. That is we don't need the more episodes.
The overall heterogeneity of effect sizes was large, that is indicating that the individual effect sizes in our data did not estimate a common population mean and that other experimental treatments or moderators may have influenced results.

4. CONCLUSIONS

Meta-analysis depicts significant level the differences of GM cotton and conventional cotton in yield response, seed cost, pesticide cost, management and labor cost and net return. Such impact took place after the GM cotton delivery. It was also reflected that the economic indicators of GM cotton substantially was no doubt in the process of implementation of its crop across the countries. Increasing yield, reducing the pesticide costs, and raising income gain was the main factors for farmers to decide to choose GM seed. Seed cost is the prominent factor, however it is able to be counterbalanced when the crop can deliver higher yield. Increasing yield can raise

the expenditure of the post harvest, however it can offset with the reduction of chemical spray.
Therefore, through in the meta-analysis this study found the positive impact in the differences of GM cotton and conventional cotton as the evidence of the publication is highly significant. Considering the absence and the presence of the potential of publication bias, it is noteworthy that the possible of bias come from viz. the different methodologies such as field survey and field trial, climatic variability, and geographical dependent from region to region, country to country, trait to trait and year to year.

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Table 1. Meta analysis of yield gain by using two different methods

Methods	Pooled Estimation	95% CI		Asymptotic		Number of Studies
		Lower	Upper	Z_Value	P_value	
Fixed	0.857	0.848	0.865	-31.769	0.000	46
Random	0.838	0.792	0.888	-6.009	0.000	

Table 2. Meta analysis of seed implementation by using two different methods

Methods	Pooled Estimation	95% CI		Asymptotic		Number of Studies
		Lower	Upper	Z_Value	P_value	
Fixed	0.438	0.402	0.477	-18.991	0.000	25
Random	0.410	0.341	0.493	-9.470	0.000	

Table 3. Meta analysis of pesticide cost by using two different methods

Methods	Pooled Estimation	95% CI		Asymptotic		Number of Studies
		Lower	Upper	Z_Value	P_value	
Fixed	6.679	6.398	6.971	86.771	0.000	28
Random	9.991	5.930	16.832	8.649	0.000	

Table 4. Meta analysis of management and labor cost by using two different methods

Methods	Pooled Estimation	95% CI		Asymptotic		Number of Studies
		Lower	Upper	Z_Value	P_value	
Fixed	0.811	0.791	0.830	-17.248	0.000	20
Random	0.871	0.743	1.021	-1.703	0.089	

Table 5. Meta data analysis of net revenue by using fixed effect size and random effect size

Methods	Pooled Estimation	95% CI		Asymptotic		Number of Studies
		Lower	Upper	Z_Value	P_value	
Fixed	0.789	0.772	0.805	-22.271	0.000	25
Random	0.714	0.593	0.860	-3.552	0.000	

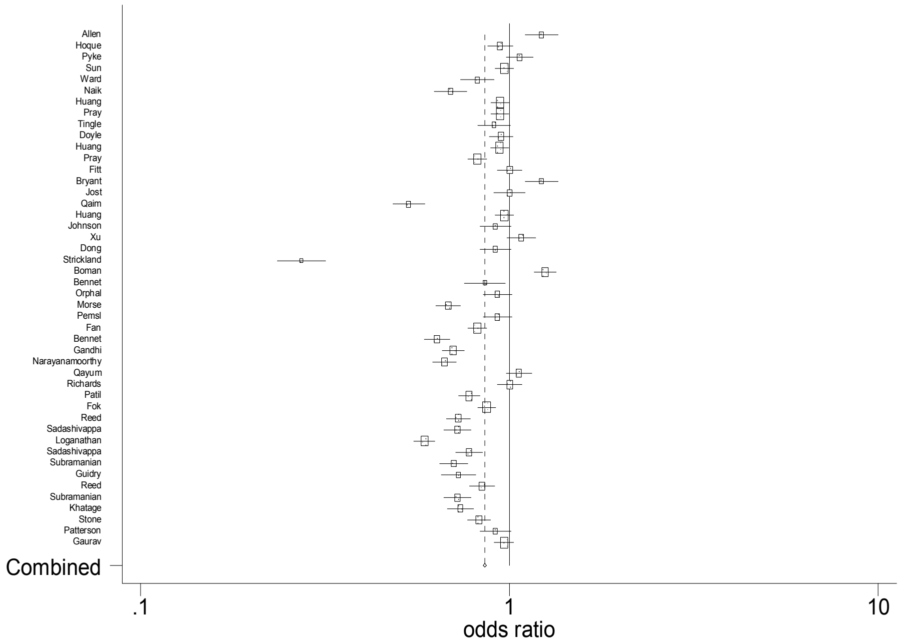

Figure 1. Random-effect Forest plots of meta analysis of yield of GM and non GM cotton

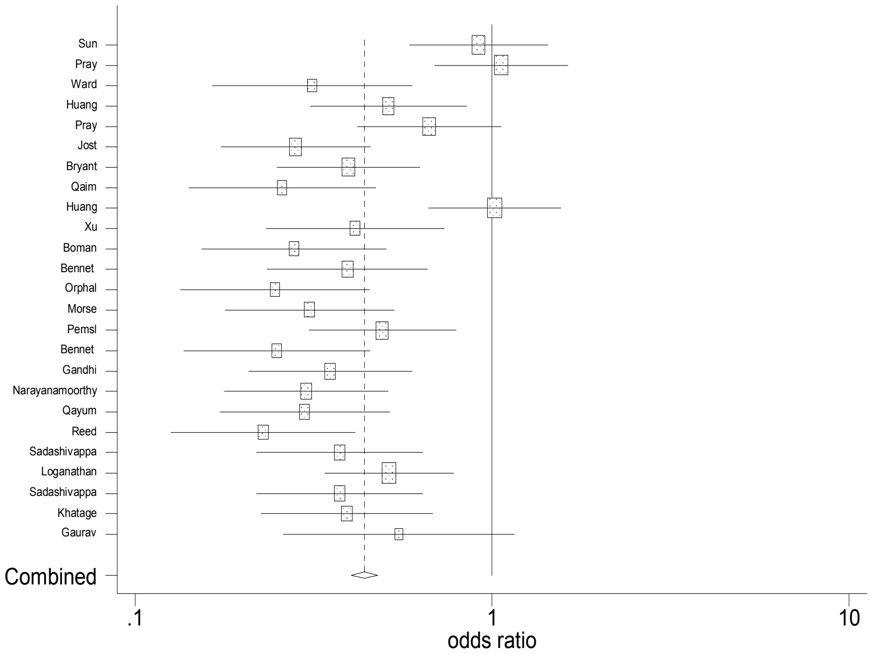

Figure 2. Random-effect Meta graph in 95% confidence limit of seed implementation

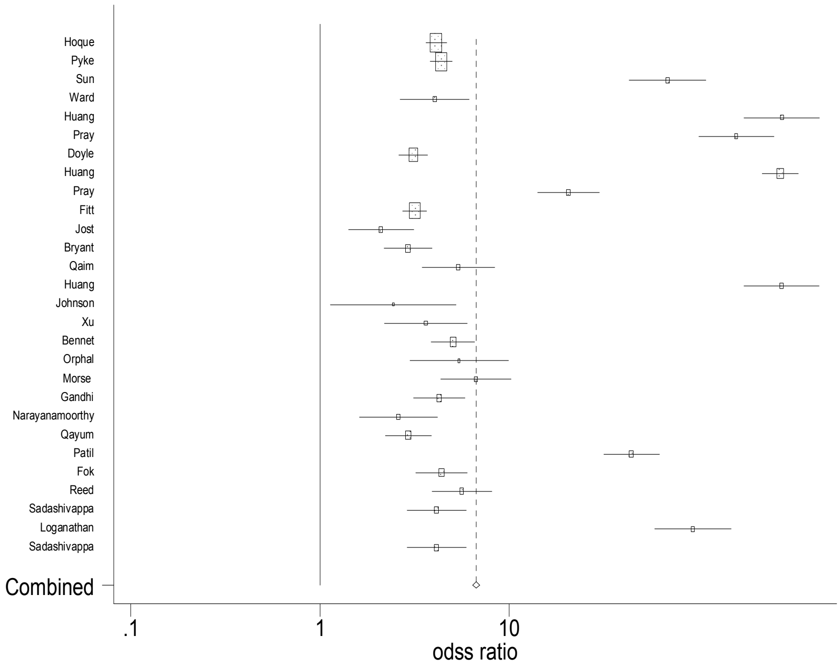

Figure 3. Random-effects forest plot of meta analysis by implementing pesticide of GM cotton and its counterpart

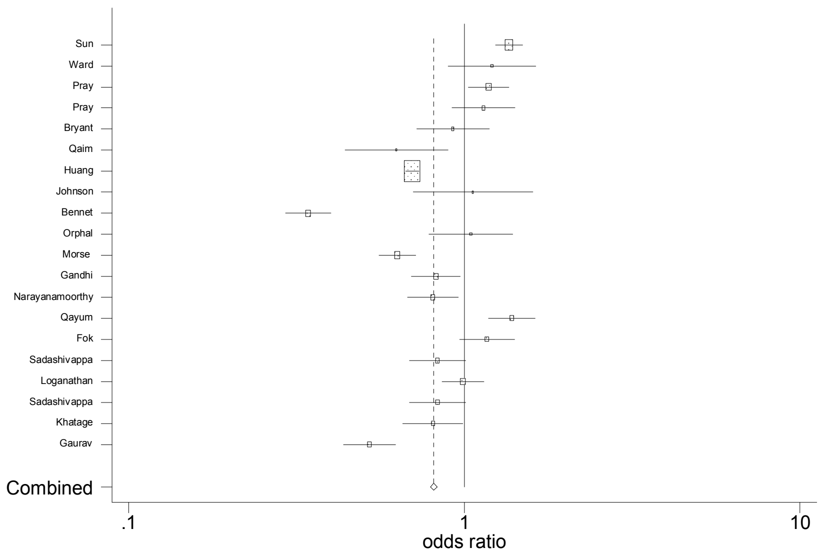

Figure 4. Random-effect Meta graph of management and labor cost of GM cotton and its counterpart

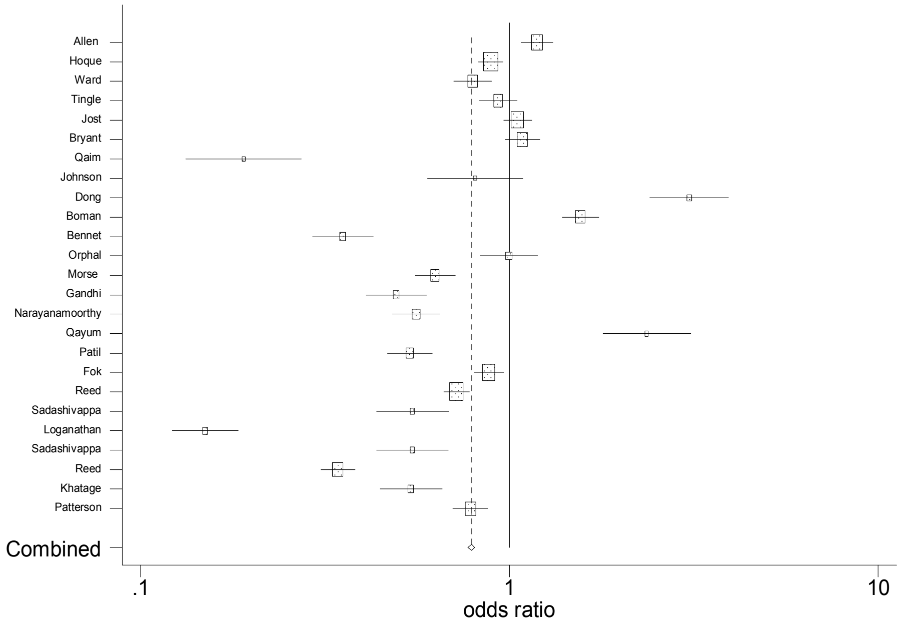

Figure 5. Forest Plot Random-effect of Net revenue of GM cotton and its counterpart

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