Evaluation of Potato Production Best Management Practices

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ABSTRACT

A 2001 survey indicated that many growers are reluctant to adopt research-based recommendations because of a perception that it is not practical or applicable to their specific farming operation. Other growers, however, appear to adopt these practices successfully. Highlighting "model" growers is a method that can be used to field-test research findings and facilitate grower adoption. The objectives of this project were to: 1) establish field demonstrations with potato (*Solanum tuberosum* L.) growers who generally follow research-based best management practices (BMPs); 2) establish plots within each field to compare BMPs with a high input, maximum yield management (MYM) approach; and 3) enhance grower confidence regarding research-based BMPs. Fourteen field trials were conducted in the Pacific Northwest during 2002-2005. Five replicates of BMP and MYM plots were established in each field. The BMPs consisted of sampling, scouting, and use of prediction models to aid in determining rate and timing of inputs to maximize returns. In contrast, the MYM approach was based on tradition and calendar timing, with a near zero tolerance for pest and nutrient limitations. The MYM plots had 1.7 to 13.2% more fertilizer and pesticide costs than the BMP plots. The MYM treatments resulted in significant marketable yield increases in three fields and decreases in two fields, with the remaining nine fields and the combined average of all 14 fields being statistically equivalent. When factoring in estimated costs, only two fields resulted in a monetary advantage with MYM treatment. In contrast, the BMP treatment resulted in significant increases in net crop value in five fields, as well as the combined average of all 14 fields (\$200 ha^{-1} or 3.2%). These field demonstrations, along with associated field days and grower meetings, have resulted in many documented changes in grower practices towards BMPs, with many more undocumented changes probable.

RESUMEN

Un estudio que se hizo el 2001 indica que muchos agricultores son renuentes a adoptar las recomendaciones basadas en la investigación, debido a una percepción poco práctica o aplicable a sus operaciones de cultivo. Otros, sin embargo, parecen adoptar exitosamente estas prácticas. El destacar a los agricultores "modelo" es un método que pude ser usado para probar en el campo los resultados de la investigación y facilitar su adopción. Los objetivos de este proyecto fueron: 1) hacer demostraciones de campo con los agricultores que cultivan papa (*Solanum tuberosum* L.) que emplean generalmente las mejores prácticas de manejo (BMPs) basadas en investigación; 2) establecimiento de parcelas dentro de cada campo las BMPs con gastos altos, un

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enfoque de manejo máximo de rendimiento (MYM); 3) incremento de la confianza del agricultor referida a los BMPs basados en investigación. Catorce pruebas de campo se realizaron el Pacífico Nor Occidental durante 2002-2005. Cinco repeticiones de BMP y de MYM se hicieron por parcela en cada campo. Los BMPs consistieron de muestreos, exploración y uso de modelos de predicción para ayudar a determinar la tasa y registro de gastos para alcanzar el máximo de ganancia. Contrariamente, el enfoque MYM estuvo basado en la tradición y distribución del tiempo, con tolerancia cero para problemas de pestes y nutrientes. Las parcelas MYM recibieron 1.7 a 13.2% de gastos en fertilizantes y pesticidas que las parcelas BMP. Los tratamientos resultaron en aumento significativo de rendimiento comerciable en tres campos disminución con los restantes nueve y el promedio combinado de los 14 campos estadísticamente equivalentes. Cuando se factorizó en gastos estimados, sólo dos campos resultaron en ventaja monetaria con el tratamiento MYM. Contrariamente, el tratamiento BMP dio como resultado un incremento significativo en cinco campos, así como el promedio combinado de todos los 14 campos (\$200 ha^{-1} o 3.2%). Estas demostraciones de campo, junto con los asociados días de campo y reuniones de agricultores, han dado como resultado muchos cambios documentados en el proceder de los agricultores hacia los BMPs, con cambios probables no documentados.

INTRODUCTION

Over the past 100 years or so, substantial amounts of time and money have been spent by private and public entities to conduct research and produce large volumes of applied-research information on potato (*Solanum tuberosum* L.) production. Potato best management practices (BMPs) are found in many publications and are largely summarized in a variety of references (Dean 1994; Flint 1986; Gardener et al. 1985; Hopkins et al. 2007; Rowe 1993; Stark and Love 2003; and Zehnder et al. 1994).

In an effort to determine how extensively BMPs have been adopted, a verbal survey of 38 growers, representing approximately 10% of the potato production in Idaho, was conducted in 2001 (Hopkins, unpublished data). These growers were presented with a list of five BMPs for Idaho conditions that had been thoroughly documented through research. The five selected BMPs included: 1) applying fertilizer based on soil sampling and research-based recommendation tables, 2) planting seedpieces at a six-inch depth, 3) cultivating at or just prior to emergence, 4) measuring actual water use and cutting back irrigation during late bulking, and 5) applying protectant fungicides just prior to row closure and 7-14 days later with additional as-needed applications based on scouting and local pathogen pressure levels. The growers were asked if they were aware of the recommendations and if they had implemented these practices on their farm. Most of the growers were aware of the recommendations, but none of the growers had adopted all five BMPs; less than half had adopted two or more BMPs, and just over one-third had not adopted any of the practices. These results were disconcerting, and efforts were directed at increasing grower adoption of research-based BMPs.

To facilitate grower adoption of BMPs, a follow-up survey was conducted and growers were asked to provide unprompted explanations as to why they did not utilize these recommendations. Their responses were compiled into a list and all participating growers were asked to rank the importance of each explanation (Hopkins et al. 2007). Most growers indicated that they were reluctant to adopt research-based recommendations because they believed that small plot research was not usually applicable to a whole farm situation due to differences in scale and management. They also indicated that research-based recommendations were not always practical, economical, or feasible for large scale production operations. Growers also found it confusing when there were conflicting recommendations between different researchers. For example, many soil scientists recommend leaving residues on the surface over winter to minimize erosion (Hopkins et al. 2007), while some pathologists recommend residue-incorporating tillage in the fall to reduce pathogen inoculum levels for common scab and Pythium seedpiece decay (Powelson et al. 1993). Moreover, growers were hesitant to change practices when their current management already appeared to be successful.

These issues, both real and imagined, have played a major role in why many of the growers ignored potentially valuable information. When asked what would help boost their confidence in research-based BMPs, most growers indicated that the number one influence would be adoption by successful and respected growers. Ironically, many growers have successfully adopted some or all of the BMPs in question. Based on these findings, the best way to facilitate grower adoption may simply be to highlight potato producers successfully using BMPs.

The objectives of this project were to: 1) establish field demonstrations with potato growers that generally follow research-based best management practices (BMPs); 2) establish plots within each of these fields to compare BMPs with a high input, maximum yield management (MYM) approach; and 3) enhance grower confidence regarding research-based BMPs. The BMPs center on a maximum economic yield (MEY) approach, as determined by many research trials conducted over the past century (Hopkins et al. 2007). In contrast, the high input or MYM approach is typically based on tradition and calendar timing, with a near zero tolerance for potential pest and nutrient problems.

MATERIALS AND METHODS

Fourteen potato field demonstrations/trials were conducted at various locations across Idaho, Oregon, and Washington over four years with either 'Russet Burbank' or 'Ranger Russet' as the test cultivars (Table 1). Plot size was 12 m by 0.9 m (4 rows) with 25 to 30 cm in-row seedpiece spacing.

Field selection criteria were based on an attempt to highlight "model growers" who best exemplified successful production and whose management coincided with research-based BMPs, with a maximum economic yield approach as a normal part of farm management. The cooperating scientists in each of the regions where trials were conducted were responsible for selecting the grower(s). Five replicates of two treatments (BMP and MYM) were established in randomized complete blocks (RCBD) in each field. This project was distinctive in that the treatments were not based on specific, controlled practices, but rather consisted of a comparison of two management approaches. There were many BMPs for growers to follow (Hopkins et al. 2007), but fertilizer and pesticide inputs were the focus of this project.

In general, the cooperating "model growers" used the following practices with regard to fertilization and pesticide BMPs. Pre-emergence fertilizer recommendations were based on reasonably intensive soil sampling and analysis with the amount of fertilizer applied derived from tables formulated from cooperative university and industry research (Lang et al. 1999; Stark et al. 2004). Typically, the amount of fertilizer recommended in these tables is for producing 90-95% of maximum yield and is based on MEY. In-season fertilizer recommendations were based on petiole analysis, again with the fertilizer applied based on MEY research. Pesticide application philosophy was similar to the fertilization approach. Initial applications of herbicides, insecticides, fungicides, and fumigants were based on field history and expected pest/pathogen pressure. Additional applications were made only if scouting, sampling, real-time reports, and forecasting models indicated a need. The entire field was managed by the grower using a BMP approach, with little input from the cooperating scientists. As such, it was intended that these fields would serve as a testament to the validity of the published BMPs.

A plot area within each field was set aside to compare BMP to MYM treatments. The BMP plots received the same treatments as the rest of the field. The MYM plots received additional fertilizer and pesticide inputs based on each field's unique circumstances. The decision to apply fertilizer and pesticides was made by the local cooperating scientist in cooperation with the grower and the advising agronomist(s). If a particular input being considered for its potential to increase yields was decided against by the BMP grower because previous research data indicated the cost would likely exceed the benefit, the input was then applied only to the MYM plots. For example, the ID1 field had a substantial number of apparent weed escapes. The grower was contemplating applying an additional herbicide application, but the grower's agronomist recognized that the emerged weed seedlings would probably be inhibited enough by the existing herbicide in the soil, and therefore an additional application would not likely prove to be cost effective. The grower decided to follow this advice for

TABLE 1—*BMP trial locations and cultivars.*

Field Identification	Year	Location (nearest city)	Cultivar
ID1	2002	Rexburg, ID	*Russet Burbank*
ID2	2003	Rexburg, ID	*Russet Burbank*
ID3	2003	Shelley, ID	*Russet Burbank*
ID4	2003	Parma, ID	*Ranger Russet*
ID5	2004	Wendell, ID	*Ranger Russet*
ID6	2004	Fort Hall, ID	*Russet Burbank*
ID7	2004	Blackfoot, ID	*Russet Burbank*
ID8	2005	Blackfoot, ID	*Russet Burbank*
OR1	2003	Hermiston, OR	*Ranger Russet*
OR2	2004	Hermiston, OR	*Ranger Russet*
OR3	2005	Hermiston, OR	*Ranger Russet*
WA1	2003	Connell, WA	*Russet Burbank*
WA2	2004	Othello, WA	*Russet Burbank*
WA3	2005	Pasco, WA	*Ranger Russet*

the whole field. However, the near zero tolerance approach called for a herbicide application in the MYM plots. The grower's decision proved to be justified, as the weeds in the areas outside the MYM plots were only slightly worse, with the effect on yield not significant.

Each entire field, including both BMP and MYM plots, typically received at least: 1) fertilizer applications based on university recommendations, 2) seed treatment for pathogen control, 3) two-way tank mix or separate applications of two herbicides, 4) insecticide as a seed treatment or applied at hilling, and 4) two fungicide applications. Those fields having a longer growing season (western Idaho, Washington and Oregon fields) tended to receive proportionally higher input rates by necessity. The additional inputs for these longer growing season areas typically included one additional insecticide application and several fungicide applications.

The added inputs for the MYM plots in each field are listed in Table 2. A majority of the fields received additional preemergence or water-run fertilizer in the MYM plots with an average rate (in kg ha^{-1}) of: 47 N (5 fields), 82 P_2O_5 (11 fields), 68 K_2O (11 fields), 45 S (10 fields), 2.6 Ca (2 fields), 2.4 Mg (2 fields), 49 Cl (8 fields), 6 Mn (11 fields), 5 Zn (6 fields), 1 B (5 fields), 1 Fe (2 fields), and 0.5 Cu (2 fields). In addition, all of the Idaho fields and two of the Washington fields had one or two additional foliar nutrient sprays (generally combined with fungicide sprays) in response to marginal petiole nutrient concentrations. The foliar nutrient sprays ranged from single element to complete nutrient regimes. The Oregon fields did not have foliar nutrient sprays, but had water-run fertilizers instead.

In addition, the MYM plots in all of the Idaho and one of the Washington fields received one to three additional foliar fungicide applications. Because the growing season in the Columbia Basin of Washington and Oregon is typically longer than it is in Idaho, the number of fungicide applications made throughout the season is usually greater. This is a good example of how BMPs may vary by region. The pathogen management BMP for fields with long growing seasons regularly requires frequent fungicide applications, whereas growers in short season areas may be able to avoid frequent fungicide

TABLE 2—*Additional inputs for "high input" plots.*[1]

	Fertilizers (kg ha^{-1})	In-Season Pesticide
ID1	Pre-Plant (66 P_2O_5, 83 K_2O, 26 S, 55 Cl, 7 Mn); 2 Foliar Sprays (8 N, 8 P_2O_5, 8 K_2O, 1 S, 0.6 Zn, 0.6 Fe, 0.6 Mn, 0.1 Cu, 0.08 B)	0.6 kg metribuzin DF, 1.4 L oxamyl L, 0.57 kg azoxystrobin, 1.7 kg mancozeb DF NT
ID2	Pre-Plant (66 P_2O_5, 83 K_2O, 26 S, 55 Cl, 7 Mn); 1 Foliar Spray (8 N, 8 P_2O_5, 8 K_2O, 1 S, 0.6 Zn, 0.6 Fe, 0.6 Mn, 0.1 Cu, 0.08 B)	0.57 kg azoxystrobin
ID3	Pre-Plant (66 P_2O_5, 83 K_2O, 26 S, 55 Cl, 7 Mn); 2 Foliar Sprays (8 N, 8 P_2O_5, 8 K_2O, 1 S, 0.6 Zn, 0.6 Fe, 0.6 Mn, 0.1 Cu, 0.08 B)	0.57 kg azoxystrobin
ID4	Pre-Plant (12 N, 57 P_2O_5, 43 K_2O, 17 S, 29 Cl, 7 Mn); 2 Foliar Sprays (8 N, 8 P_2O_5, 8 K_2O, 1 S, 0.6 Zn, 0.6 Fe, 0.6 Mn, 0.1 Cu, 0.08 B)	2 - 0.57 kg azoxystrobin
ID5	Pre-Plant (83 S, 11 Zn, 7 Mn); 3 Water Injections (105 N); 1 Foliar Spray 2 qt Che-Plex (N, S, Zn, Fe, Mn)	0.57 kg azoxystrobin
ID6	Pre-Plant (66 P_2O_5, 66 K_2O, 55 S, 44 Cl, 6 Zn, 6 Mn, 2 B); 1 Foliar Spray (4 N, 4 P_2O_5, 4 K_2O, 0.5 S, 0.3 Zn, 0.3 Fe, 0.3 Mn, 0.05 Cu, 0.04 B)	0.57 kg azoxystrobin, 0.17 L fluazinam 500F, 0.57 kg azoxystrobin
ID7	Pre-Plant (66 P_2O_5, 66 K_2O, 55 S, 44 Cl, 6 Zn, 6 Mn, 2 B); 1 Foliar Spray (3 N, 9 P_2O_5, 1 K_2O, 0.3 Zn, 0.3 Fe, 0.3 Mn, 0.05 Cu, 0.04 B)	2 - 0.17 L fluazinam 500F, 1lb 0.45 kg chlorothalonil
ID8	Pre-Plant (66 P_2O_5, 83 K_2O, 110 S, 55 Cl, 7 Mn); 3 Water Injections (55 P_2O_5, 36 K_2O); 2 Foliar Sprays (3 N, 9 P_2O_5, 1 K_2O, 0.3 Zn, 0.3 Fe, 0.3 Mn, 0.05 Cu, 0.04 B)	0.45 kg chlorothalonil, 2 - 0.17 L fluazinam 500F
OR1	3 Water Injections (44 N, 150 P_2O_5)	2 - 0.5 L oxamyl L, 3.8 L propargite
OR2	2 Water Injections (30 N, 100 P_2O_5, 0.5 Zn, 0.5 Fe, 0.5 Mn, 0.1 Cu, 0.01 B); 2 Foliar Sprays (4 N, 5 Ca)	none
OR3	3 Water Injections (44 N, 150 P_2O_5, 1 Zn, 1 Fe, 1 Mn, 0.2 Cu, 0.02 B)	none
WA1	Pre-Plant (77 P_2O_5, 77 K_2O, 51 Cl, 6 Zn, 11 Mn)	0.45 kg chlorothalonil
WA2	2 Foliar Sprays (0.2 N, 0.05 K_2O, 6 S, 0.2 Ca, 2.4 Mg, <0.05 Zn, <0.05 Fe, <0.05 Mn, <0.05 Cu, <0.05 B), 0.1 gamma aminobutyric acid 0.1 kg L-Glutamic acid	none
WA3	2 Foliar Sprays (6 S, 2.4 Mg)	0.2 L fluazinam 500F

[1] The additional applications for the high input plots shown in this table were applied in addition to the base BMP rates applied to each field.

applications, especially when humidity/rainfall and local pathogen pressure is low. As a result, the BMP growers in southcentral and eastern Idaho applied fungicide only one to three times, giving an opportunity for additional applications on the MYM plots. Alternatively, the BMP growers in Oregon and Washington applied fungicide more frequently, and this resulted in a lack of opportunity to apply additional fungicide in the MYM plots. In contrast to fungicide applications, the differences between BMP and MYM treatments for the other pesticides were minimal. Only one field had additional herbicide, one had supplementary nematicide, and two had additional insecticides in the MYM plots.

For the MYM plots, water-run and foliar applications of fertilizers and pesticides were applied with compressed CO_2 back-pack sprayers calibrated to deliver label rates with $< 5\%$ variation between nozzles. Foliar sprays were applied with manufacturer recommended spreader/stickers to enhance foliar absorption. Water-run treatments were simulated by applying a fertilizer/water mixture with the back-pack sprayer immediately prior to overhead irrigation and in the early morning to avoid the drying of product on leaves. Dry fertilizer was applied evenly across each plot with a spinning broadcast hand spreader and then incorporated as a part of the normal field operations (bedding or hilling). Soil samples, to determine pre-emergence fertilizer rates, were taken randomly throughout the field (~15 cores per field) to a depth of 30 cm. The fourth fully emerged petiole was collected from the top of ~40 plants across each treatment to determine in-season nutritional needs. Soil samples were submitted to a commercial laboratory for drying and analysis using approved methods.

Tubers were harvested from 6 m of the center two rows of each plot, by hand or machine, to determine yield within one to seven days of the grower's harvest date. Tuber fresh weights were determined gravimetrically. Marketable yields were determined by combining all US No. 1 and US No. 2 size grades. US No. 1 and, in some cases, US No. 2 tubers were separated into various size categories. Break points for size categories included: 114, 170, 227, 284, 341, and 397 g. Cull yields were determined by combining all tubers that were undersized (< 114 g), malformed, or had external physiological, pest, or pathogen-related defects. A random sampling of each of the tuber size categories over 114 g was saved for specific gravity analysis and internal defect evaluation (minimum of eight tubers per plot). A composite of tubers was used to determine tuber specific gravity using the weight-in-air/weight-in-water method (Kleinschmidt et al. 1984). Internal defects were determined by inspecting a sub-sample of at least eight tubers from each plot and cutting each tuber in half along the longitudinal axis.

Gross crop values were estimated by using five-year average regional processing potato prices of \$109.03 Mg^{-1} for marketable potatoes and \$38.55 Mg^{-1} for cull potatoes. This simplified, least common denominator approach in determining crop value (as compared to using price incentives for size, specific gravity, etc.) was used because of the diversity of market scenarios faced by the growers across regions and time during the project. Although the main emphasis presented here is the non-incentive adjusted pricing, incentive adjusted scenarios were also applied to the yield data and presented in part below.

Net crop value was estimated by subtracting the cost of the added MYM inputs from the gross crop value. The cost of added inputs was estimated by determining the average prices of the inputs and custom application charges at the time of application. Field response was determined by subtracting the yields and crop values of the BMP from the MYM plots.

Differences across treatments were determined by ANOVA, with the PROC GLM procedure in SAS software (SAS Institute 1990) with significance indicated at $P < 0.05$ unless otherwise noted. Statistical analysis was conducted on yield and gross/net return parameters by combining individual field data with treatment and field location as dependent variables. Yield and gross/net return parameters for individual fields were analyzed separately when the treatment by field location interaction was significant.

The final objective was achieved by conducting several public field days located at some of the model grower's fields, as well as at other grower meetings, and with various extension and popular press publications. In addition, growers expressing interest in adopting BMPs were provided one-on-one assistance in evaluating their operation.

RESULTS

Marketable, cull, and total yields for BMP and MYM treatments were statistically equivalent when evaluated across all fields (Table 3 and Figure 1). In addition to the combined analysis, each individual field was analyzed separately due to the significant interaction between field location and treatment ($P = 0.0094$). MYM treatment resulted in increases in total and

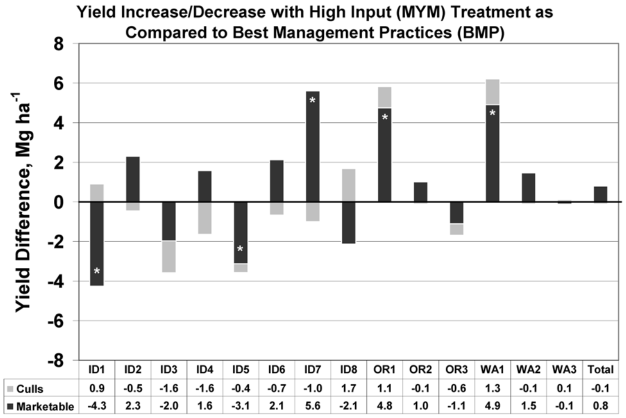

FIGURE 1.

Yield increases or decreases with high inputs for 14 Pacific Northwest fields during 2002-2005. The yield differences were determined by subtracting the marketable and cull yields for BMP from MYM plots (MYM = high input, maximum yield management with a near zero tolerance for pest and nutrient problems; BMP = best management practices based on research with maximum economic yields). The marketable category includes all US No. 1 and No. 2 tubers with the remaining tubers as culls. An "*" indicates statistical significance for the marketable yields for the field indicated at the alpha 0.05 level. Cull yields were statistically equivalent for all fields.

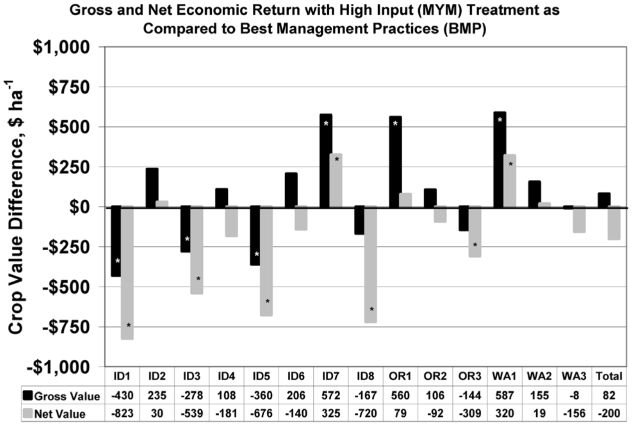

FIGURE 2.

Gross and net crop value increases or decreases with high inputs for 14 Pacific Northwest fields during 2002-2005. The differences were determined by subtracting the gross and net crop values for BMP from MYM plots (MYM = high input, maximum yield management with a near zero tolerance for pest and nutrient problems; BMP = best management practices based on research with maximum economic yields). Gross crop value was estimated based on five year averages and net value was estimated by subtracting the cost of additional inputs from gross crop value. An "*" indicates statistical significance for the field indicated at the alpha 0.05 level.

marketable yield for three fields (ID7, OR1, and WA1) and significant decreases in total yield and marketable yield in two fields (ID1 and ID5). Additionally, MYM treatment resulted in a decrease in total yield from the BMP treatment in the ID3 field, but marketable yield was not significantly different. Of the six fields that exhibited differences between treatments in total yields, four were Russet Burbank and two were Ranger Russet. It should be noted that most of the Ranger Russet fields were located in western Idaho, Oregon and Washington. The longer growing season in these regions compared to that of eastern Idaho (where Russet Burbank was the predominant cultivar grown) limits our ability to evaluate cultivar response to BMP management practices.

Individual grade and size categories were statistically equivalent when evaluated across all fields (data not shown). In addition to the combined analysis for individual grade and size categories, each individual field was analyzed separately due to the significant interaction between field location and treatment. Tuber size profiles of the MYM and BMP treatments within the ID3, OR2, WA2, and WA3 fields were not significantly different. For the remaining fields, there were some tuber size profile differences between the MYM and BMP treatments, but there were no consistent trends or significant impacts to the objectives of this study, and therefore the data are not shown. For example, for the fields having significant increases in total and marketable yield with MYM treatment, the difference was due to an increase in US No. 1 tubers for the ID7 and OR1 fields, but for the WA1 field, the difference was due to a significant increase in US No. 2 tubers. For the fields having significant decreases in total yield with MYM treatment, the differences in the ID1 and ID5 fields were due to significant decreases in US No. 1 tubers, but the ID3 field showed no differences in any individual grade or size category.

Only one field exhibited differences in tuber specific gravity (data not shown), where the BMP treatment was 1.081 versus 1.089 for the MYM treatment.

The average gross crop value difference of MYM over BMP treatment was \$82 ha^{-1}, which was not significantly different (Figure 2). A significant treatment by location interaction was observed for gross crop value, and therefore individual locations were analyzed separately. Not surprisingly, the fields showing differences in total yield (ID1, ID3, ID5, ID7, OR1, and WA1) also were different in gross crop value (Figure 2). Gross crop values between MYM and BMP in the remaining fields were statistically equivalent.

The average net crop value (factoring in cost of added inputs for MYM treatments) was not different at $P < 0.05$ but was significantly different at $P < 0.10$, with a decrease of \$200 ha^{-1} with MYM treatment. As with gross crop value, the treatment by location interaction was significant for net crop value and, therefore, analyzed by individual fields. The MYM treatment resulted in an increase in net crop value in just two of the fourteen fields (ID7 and WA1) (Figure 2). Five fields (ID1, ID3, ID5, and ID8 and OR3) showed a decrease in net crop value with MYM treatment. Net crop values with MYM and BMP treatments in the remaining fields were statistically equivalent.

DISCUSSION

This project demonstrated that potato growers following BMPs can grow a similar crop with less cost and fewer dollars at risk of loss than if they were to follow a maximum yield approach. As the "model" growers selected were believed to be among the better growers in the region, it is not surprising that their yields and tuber quality were mostly greater than local averages (National Agricultural Statistics Service 2002, 2003, 2004, 2005). The BMPs consist of using sampling, scouting, and prediction models to aid in determining chemical input rate and timing. The BMPs center on a MEY approach, as determined by many research trials conducted over the past century (Hopkins et al. 2007). In contrast, the high input or MYM approach is typically based on tradition and calendar timing, with a near zero tolerance for potential pest and nutrient problems.

The high input plots in this project received 1.7% to 13.2% more fertilizer and pesticide (cost basis) than the BMP plots in this study. A casual observation of these additional inputs used in this project would suggest that the differences in chemical inputs between the BMP and MYM approaches lie mainly with fertilizer and fungicide, and not with herbicide, insecticide, and nematicide. This is a noteworthy observation that may be true in general, but should not be concluded definitively from this project, as it may simply be an artifact or bias of the cooperating scientists, growers, and agronomists.

The average yield increase with MYM treatment across all fourteen fields was 0.8 Mg ha^{-1} marketable and 0.7 Mg ha^{-1} total yield, which were not statistically significant. Differences in individual tuber grade and size categories varied and showed no clear trends when examining BMP vs. MYM in individual fields.

The added inputs of MYM treatment resulted in increases in marketable yield, total yield, and gross crop value in only three of the fourteen fields over the four years of this trial. The likely reason for the increased yield in the OR1 field was due to mite damage in the BMP plots, resulting in a re-examination of the management practices for mite control. For the WA1 and ID7 fields, the difference in yield was likely due to fertility differences, as pathogen damage in the BMP and MYM plots was similar, thus likely ruling out differences caused by fungicides. It is not surprising that these two fields showed yield increases that were likely due to higher than recommended fertilizer rates which could be explained by random variation and/or growth conditions con-

TABLE 3—*Yield results with BMP and MYM treatments for 14 Pacific Northwest fields during 2002–2005.*

		Yield, Mg ha^{-1}					
Field ID	Treatment	Marketable		Cull		Total	
ID1	BMP	47.2	*	7.2	NS	54.3	*
	MYM	42.9		8.1		51.0	
ID2	BMP	41.1	NS	11.3	NS	52.5	NS
	MYM	43.5		10.9		54.3	
ID3	BMP	30.7	NS	9.7	NS	40.3	*
	MYM	28.7		8.0		36.7	
ID4	BMP	61.0	NS	11.6	NS	72.6	NS
	MYM	62.6		10.0		72.6	
ID5	BMP	58.9	*	7.8	NS	66.8	*
	MYM	55.8		7.4		63.2	
ID6	BMP	48.2	NS	12.9	NS	61.0	NS
	MYM	50.3		12.2		62.5	
ID7	BMP	38.2	*	10.4	NS	48.6	*
	MYM	43.8		9.4		53.2	
ID8	BMP	33.8	NS	12.8	NS	46.6	NS
	MYM	31.7		14.4		46.1	
OR1	BMP	66.8	*	12.9	NS	79.7	*
	MYM	71.6		14.0		85.6	
OR2	BMP	83.6	NS	6.0	NS	89.6	NS
	MYM	84.6		5.9		90.5	
OR3	BMP	84.7	NS	10.3	NS	95.0	NS
	MYM	83.6		9.7		93.3	
WA1	BMP	55.1	*	11.9	NS	67.0	*
	MYM	60.0		13.2		73.2	
WA2	BMP	48.4	NS	14.3	NS	62.7	NS
	MYM	49.8		14.2		64.1	
WA3	BMP	62.5	NS	6.7	NS	69.2	NS
	MYM	62.4		6.8		69.2	
Total	BMP	54.3	NS	10.4	NS	64.7	NS
	MYM	55.1		10.3		65.4	

* = statistical significance at $P < 0.05$; NS = not statistically significant

ducive for higher than expected yields. Regardless, the important conclusion is that BMPs resulted in a financial advantage in the majority of fields evaluated.

In contrast, the MYM treatment resulted in total yield and gross crop value decreases in three fields, with two also showing decreases in marketable yield. A possible reason for the yield loss due to MYM in the ID1 field was herbicide toxicity, although the label rate was applied. However, it is also possible that the slightly higher rates of fertilizer may have caused yield reductions in this field due to phosphorus-induced micronutrient deficiencies or other possible interactions. The reason for the yield decrease in the ID3 field is also in question, as the fertilizer and fungicide applied should not have resulted in yield decline. The reason for the yield decline in the ID5 field was likely due to the N applied in the MYM plots, causing excessive vine growth at the expense of tuber bulking and maturity. The N applied was in excess of recommended fertilizer BMPs and resulted in a yield and crop value loss. Although it is pertinent to discuss and speculate why BMPs performed better or worse than MYM in each field, it is important to remember that discovering the reasons for these differences was not an objective of the study. Rather, the focus is on the economic comparison of these two management approaches (BMP and MYM).

Three fields had significant increases in gross crop value and three fields had significant decreases with MYM, with the remaining eight being statistically equivalent. The average gross crop value increase with the MYM treatment across all fourteen fields was \$82 ha^{-1}, which was not significant. When factoring in the estimated cost of the added inputs, MYM resulted in a significant increase in just two fields and decreases in five fields. When averaged across all fourteen fields, the net crop value was \$200 ha^{-1} (3.2%) less for the MYM treatment than the BMP.

Although a simple marketable vs. cull comparison (common to processing potato contracts) was used in this study, grower contracts and open market payouts often take into account various combinations of incentives for specific gravity and US No. 1 and size percentages. The gross and net crop values reported would be different when different incentives are applied. For example, incentives paid for higher percentages of US No. 1 tubers result in further separation from the already significant differences in gross and net crop values for the ID1, ID5, ID7, and OR1 fields. In these cases, the BMP treatment shows greater increases in crop value for the ID1 and ID5 fields, but the MYM treatment shows greater increases for the ID7 and OR1 fields. In contrast, the difference in crop value can be diminished (depending on the magnitude of the grade incentive) for the WA1 field, due to the fact that its increase in marketable tubers with MYM treatment was due to an increase in US No. 2 and not US No. 1 tubers. Another example of a change in crop value was observed for the OR3 field, with the significant decrease in net crop value with MYM treatment potentially being nullified if a large enough incentive for tuber specific gravity was applied.

An infinite number of crop value scenarios could be applied to the data from this project. Indeed, many different base crop values and incentive adjustment scenarios were evaluated (data not shown). However, none of these scenarios resulted in an increase in net crop value for MYM over BMP treatment when averaging the results of all 14 fields. In fact, it took an improbable three- to four-fold increase in the average marketable and cull tuber pricing for the net crop value of the MYM treatment to break even with the BMP treatment. Furthermore, it took over a six-fold increase in prices before the MYM treatment resulted in a significant increase in net crop value over the BMP treatment.

Higher cost of production represents more dollars at risk for MYM growers. Although the average yield and gross crop value were statistically equivalent, this financial risk factor combined with the slightly significant decrease in net crop value, showed that the BMP approach is a superior management style over maximum yield management using higher inputs.

The results of this project were highlighted in many grower workshops and seminars, as well as several field days held at the some of the demonstration fields during the past four years. One of the primary objectives of this project was to instill confidence in growers with regard to research-based BMPs. The success of this aspect of the project has been documented in Idaho with one-on-one grower follow up surveys. Grower practices changed toward a BMP style of management on over 242,000 hectares. As not all growers/agronomists were contacted, many more undocumented changes are likely.

Many of the growers from the original survey from which this project had its roots were surveyed again at the end of the project in 2005 (Hopkins, unpublished data). They nearly unanimously stated that they gained confidence in the BMPs as a result of the project and that they had adopted many of the recommended BMPs on their own farms. They also stated that the two factors that most influenced their adoption of BMPs were that the project was conducted at field scale in cooperation with “model growers” and that multiple practices were integrated into a management style (systems approach). Although the methods of this project do not lend themselves to traditional scientific evaluation of individual management practices, the approach to evaluate and promote these research-based recommendations in grower fields serves as a model for BMP adoption.

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