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FOREST RESEARCH REPORT

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DROP SPECTRUM COMPARISON OF FIVE AERIAL APPLICATION NOZZLE ASSEMBLIES

INTRODUCTION

In Nova Scotia, Vision® (active ingredient: glyphosate 356 grams/litre) is the most common aerially-applied forestry herbicide. These applications are made with helicopter mounted spray systems utilizing various nozzle components and configurations. Although the nozzles are similar in size and output, they produce a noticeably different distribution of drop sizes (drop spectrum). The droplets generated commonly range in diameter from 10 to 2000 micrometres (µm) (Bode et al, 1981). Droplets less than 100 µm are undesirable due to their ability to drift off-target while droplets greater than 1000 µm result in reduced coverage and effectiveness (Akesson, 1987). The manufacturer of Vision® (Monsanto) recommends a droplet size range of 250 to 500 µm for effective vegetation control with their product. This range reflects a compromise between good drift control and adequate coverage (Monsanto, 1990).

The purpose of this report is to determine the drop size distribution of five nozzle assemblies commonly used in forestry: the D6 JET, D8 JET, D8-45, D8-46 and 8010 LP.

METHODS

Field Work

On an abandoned airstrip in Stanley, Hants County, a flight line was established approximately 75 metres (m) from the surrounding forest cover. A 57 m long data-collection line was laid out perpendicular to, and centered on the flight line. Kromekote cards measuring 10 x 10 centimetres were sequentially numbered from 1 to 20 and affixed to the data-collection line at 3 m intervals (Figure 1). These cards

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were used to record the droplets emitted during the trial.

A 0.2% solution of Bulls Eye® marker dye in water was pumped into a Jet Ranger 206 B helicopter equipped with a Simplex® model 4900 spray system. Boom width was 8.3 m with 51 active nozzles, twenty-two on each side plus seven nozzles between the skids. Boom nozzles were spaced evenly at approximately 15 cm and were angled in-flight at 135° (45° back). Passes over the cards were made at approximately 105 kilometers per hour at a release height of about 10 m. The center point of the flight line was clearly marked such that the pilot was able to center the pass accurately. Two passes were conducted for each nozzle type.

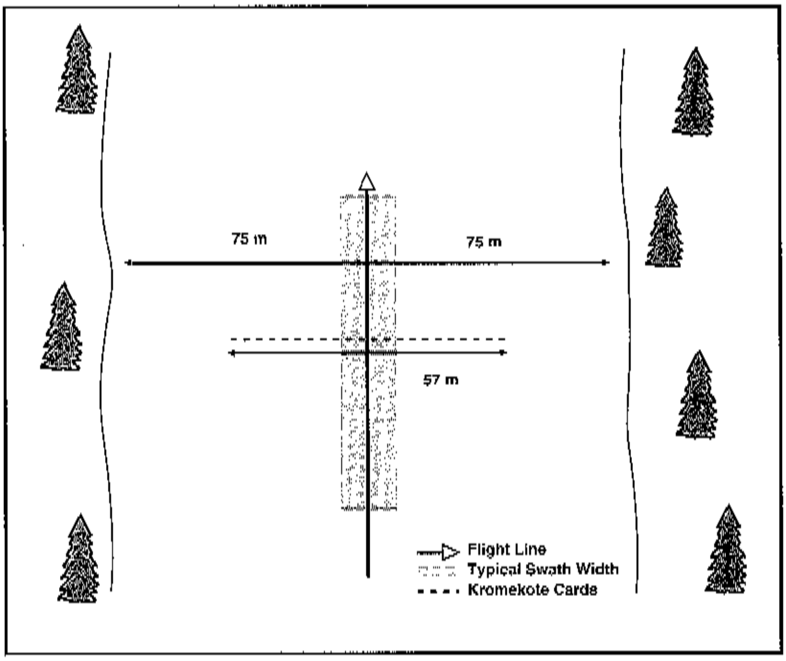

Figure 1. Schematic of data collection layout.

After each pass, the kromekote cards were collected and then replaced with fresh cards.

Through the use of a Crop Hawk® flow rate monitor, the pilot adjusted the pressure in flight, to maintain a total solution output of between 35 and 50 litres per hectare. This was necessary due to the difference in the orifice size of the different nozzle types. Appendix I shows the flow rate, application rate, boom, pressure and weather data for each pass.

Laboratory and Data Analyses

The following drop size determination was completed by Warnica (1990). Cells on the kromekote cards were sampled based on double digit random numbers generated from Mendenhall (1987). Sampling intensity ranged from 3 to 10% of each card to keep the total number of droplets sampled for each nozzle approximately equal. The diameter of each droplet within each sample cell was measured using a 12 power microscope with a graduated eye piece. When oval drops were encountered, they were measured across their length and width with the average being recorded as the diameter. Drops on sample cell boundaries were measured only if one half their area was within the designated cell. Droplets were measured in units, as defined by the graduated eyepiece, with each unit equalling 83 μm in size. On impact with the kromekote card, a droplet forms a stain larger in diameter than the original drop. The relationship between the droplet and the stain is known as the spread factor and must be determined for each sample surface and

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liquid. Barry et al. (1978) found that the spread factors for a .1% and .5% dye solution in water on kromekote cards were 1.7 and 2.0 respectively. For the purpose of this report, a spread factor of 1.8 was used, meaning, the recorded stain is actually 1.8 times larger than the original droplet. This reduced the value of each graduated unit to 46 μm in size prior to impacting on the kromekote card. Therefore, all droplets less than or equal to 46 μm fell into the 46 μm class; all droplets greater than 46 and less than or equal to 92 μm fell into the 92 μm class, etc. (Appendix II). Classes were then grouped to provide four ranges of drop sizes. The drift prone range was defined as 0 to ≤231 μm. The manufacturer's recommended range (Monsanto) was defined as >231 to ≤461 μm[1]. Recognizing the potential for good efficacy of slightly larger drops, an acceptable range of >231 to ≤1153 μm was also defined. All drops larger than 1153 μm were grouped in the over size range due to the efficacy reduction and poor leaf area coverage associated with these drop sizes (Table 1).

Once actual drop sizes were calculated, volumes were determined using the volume equation for a sphere. Drops were then categorized in the aforementioned diameter ranges and volumes and percent of total volumes were calculated.

Table 1. Droplet diameter range classification

Range Name	Lower Diameter Limit (>μm)	Upper Diameter Limit (≤μm)
Drift Prone	–	231
Manufacturers Recommended	231	461
Acceptable	231	1153
Over Size	1153	–

RESULTS AND DISCUSSION

D6-JET

The D6-JET (disc type, 6/64" orifice) nozzle lacks a swirl plate which results in the production of a solid stream of liquid during operation. Formation of the droplets is dependent almost entirely on wind shear created by the forward motion of the helicopter (Matthews, 1984). This produces a broad spectrum of droplet sizes (Figure 2). The D6-JET produced drops between the 92 and 4150 μm classes inclusive (Appendix II). Only 18% of the total volume was in the acceptable range and only 4% in the range recommended by the manufacturer of the herbicide (Table 2). Although less than 1% of the volume was in the less than 231 μm category (defined as the drift prone range), 82% was in the larger than recommended category. The droplets produced in this larger category are less

1. **Monsanto recommends a range of 250-500 μm. Since the class limits did not correspond, the manufacturer's range was adjusted to >231 - ≤461 μm.**

Table 2. Percent of droplet volume for each nozzle by diameter class.

Droplet Size Range Classification	Midpoint of Diameter Class	Nozzle Type				
		D6-JET	D8-JET	D8-45	D8-46	8010
Drift Prone (≤231 µm)	115	0.4	0.3	4.2	1.2	3.0
Acceptable (>231 to ≤1153 µm)						
Manufacturers Recommended (>231 to ≤461 µm)	345	3.6	2.6	22.2	8.0	19.8
	576	4.9	4.0	35.2	12.2	20.6
	806	3.1	6.6	16.7	13.7	9.8
	1037	6.3	7.1	10.7	14.5	17.3
Total		**17.9**	**20.3**	**84.8**	**48.4**	**67.5**
Over Size (>1153 µm)	1268	6.2	8.2	4.3	7.7	13.7
	1498	5.6	10.4	6.7	10.9	15.9
	1729	7.0	7.5	0	12.9	0
	1959	6.0	12.9	0	7.3	0
	2190	7.3	11.9	0	6.7	0
	2420	1.6	12.0	0	4.9	0
	2651	5.3	4.9	0	0	0
	2882	2.6	6.5	0	0	0
	3112	3.3	0	0	0	0
	3343	11.6	5.1	0	0	0
	3573	4.9	0	0	0	0
	3804	0	0	0	0	0
	4034	20.2	0	0	0	0
Total		**81.6**	**79.4**	**11.0**	**50.4**	**29.6**

Monsanto® recommends a range of 250 - 500 µm. Since the class limits did not correspond, the manufacturers range was adjusted to >231 - ≤461 µm.

efficacious due to the reduction in coverage on target vegetation. Twenty percent of the total volume produced by the D6-JET was contained in the 4034 µm class. This volume was accounted for by only three droplets. The volume contained in one 4000 µm droplet is equivalent to over 1200 droplets, 375 µm in size.

D8-JET

The D8-JET (disc type 8/64" orifice) as in the D6-JET, has no swirl plate but has an orifice of a slightly larger size. The difference in the orifice size produces a similar solid stream at a lower pressure, therefore results were found to resemble those for the D6-JET. The droplet spectrum included drops from the 92 µm class to the 3320 µm class (Appendix II). The drift prone range of droplets accounted for less than 1% of the total volume, while 79% of the volume was in the larger than recommended category (Figure 3). This leaves only 20% of the total volume in the recommended size class range, with 3% of the volume in the category recommended by the herbicide manufacturer

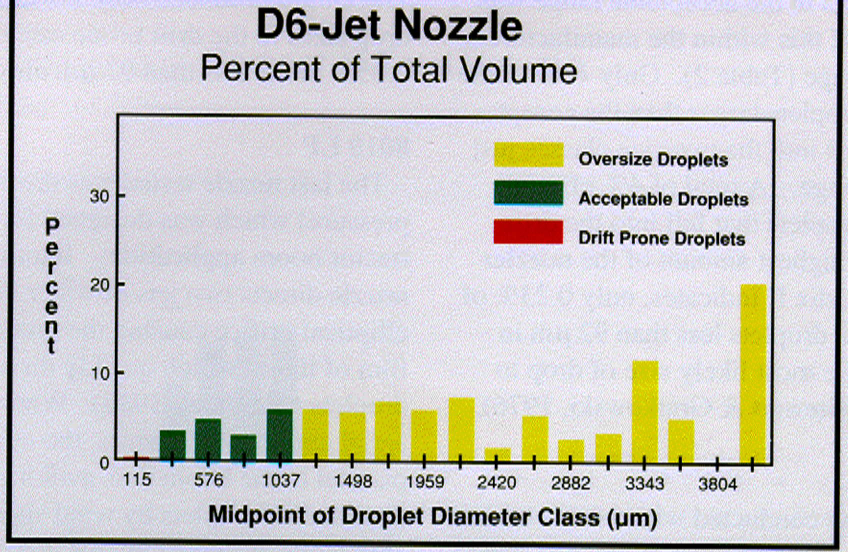

Figure 2. The distribution of spray volume by droplet diameter class emitted by the D6-Jet nozzle.

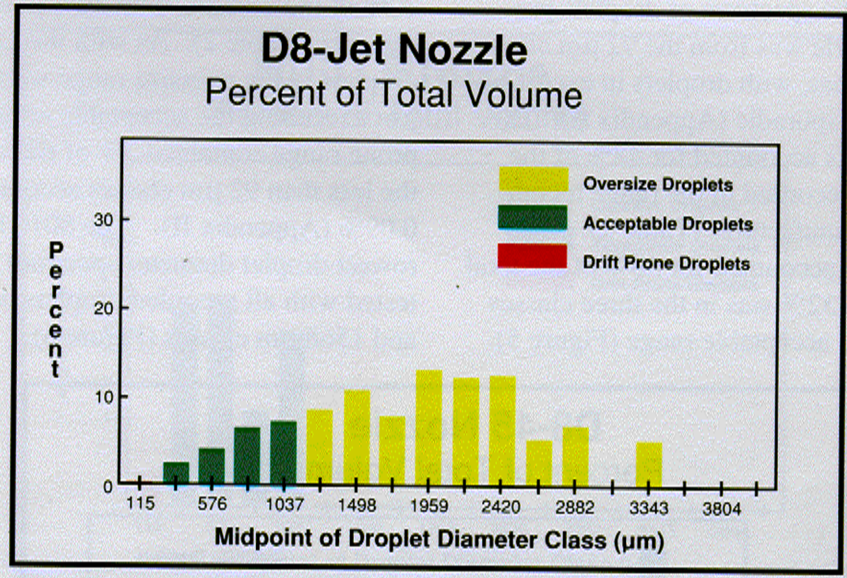

Figure 3. The distribution of spray volume by droplet diameter class emitted by the D8-Jet nozzle.

(Table 2). Again, with nearly 80% of the total volume in the large drop class, coverage will be considerably reduced, resulting in a reduction in efficacy.

D8-45

With the incorporation of a #45 swirl plate, the D8 nozzle (D8-45) produced the highest percent of volume in both the acceptable and the manufacturer's recommended range. The inclusion of the #45 swirl plate changes the solid stream to a hollow cone spray pattern resulting in the formation of droplets by the nozzle. In addition, the swirl plate breaks up the excessively large droplets while combining smaller droplets into larger ones (Matthews 1984). Droplet size, for the D8-45, was found to vary between the 46 and the 1614 µm classes, a considerable reduction in range from both the D6 and D8 JET nozzles (Figure 4). The total volume of droplets in the acceptable range was 85%, with 22% of this within the manufacturers recommended range (Table 2). Only 11% of the volume was in droplets larger than the acceptable range and fell into the two size classes just exceeding that range. A total of 4% of the volume was in droplets that fell into the drift prone range, the highest amount of the nozzles tested. As Appendix II indicates, only 0.23% of the volume fell in droplets less than 92 µm in size, this being the most likely size of drop to move off target (Stewart & Gratkowski, 1976).

D8-46

The final testing conducted with the D8 orifice involved the use of a #46 swirl plate. The #46 swirl produces the same hollow cone pattern as the #45 swirl but at a higher flow rate for a given pressure. The spectrum of droplets produced by this nozzle was from the 92 µm class to the 2536 µm class, with droplets in excess of 1844 µm few and sporadic (Appendix II). The acceptable droplets accounted for 48% of the volume with 8% recorded in the range recommended by the manufacturer (Table 2). The over size droplets accounted for 50% of the total volume, of which 32% was in the three classes just exceeding the acceptable range (Figure 5). The D8-46 produced only 1% of its volume in drop sizes in the drift prone category with 0.05% in the less than 92 µm classes.

8010 LP

The last nozzle tested was the 8010 LP (low pressure) which was designed for high volume tractor boom applications. Internally the 8010 nozzle directs two jets of water that meet at an elliptical orifice causing the production of a thin film of liquid which quickly disintegrates into droplets (Matthews 1984). When in use on aerial application devices, the nozzle is aligned parallel to the boom thus avoiding partial destruction of droplets by wind shear. The acceptable range produced by this nozzle, accounted for 68% of the total volume of spray. The manufacturers recommended range contained 20% of the volume, with 30% in the oversize category (Table 2). As with the D8-45, the droplets in the oversize range were in the classes just exceeding the acceptable range. The drift prone range contained 3% of the volume, with the less than 92 µm classes accounting for 0.09% (Appendix II). The 8010 had the narrowest droplet diameter spectrum of all nozzles tested with all recorded droplets between the 46 and 1568 µm classes (Figure 6).

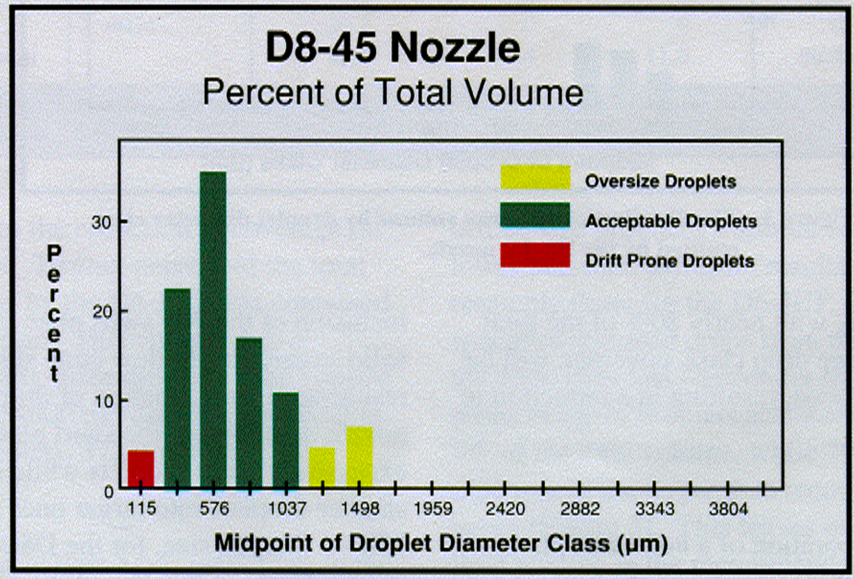

Figure 4. The distribution of spray volume by droplet diameter class emitted by the D8-45 nozzle.

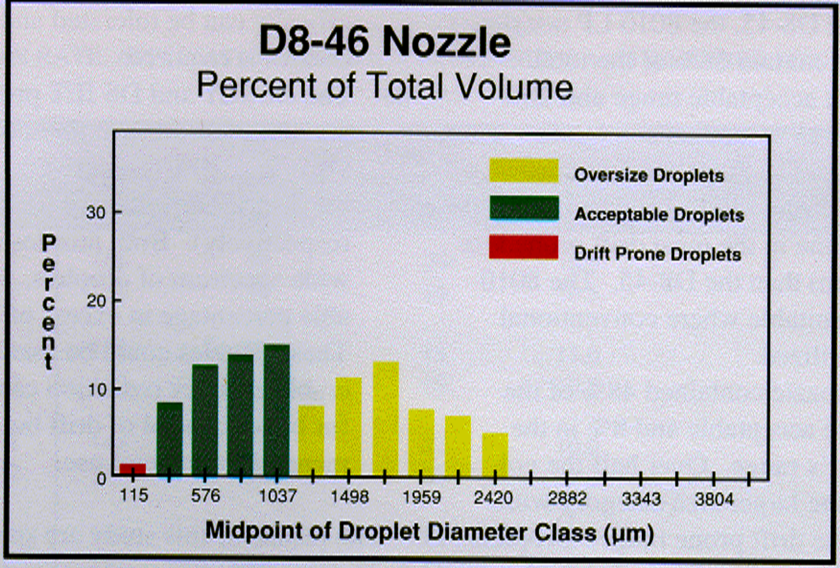

Figure 5. The distribution of spray volume by droplet diameter class emitted by the D8-46 nozzle.

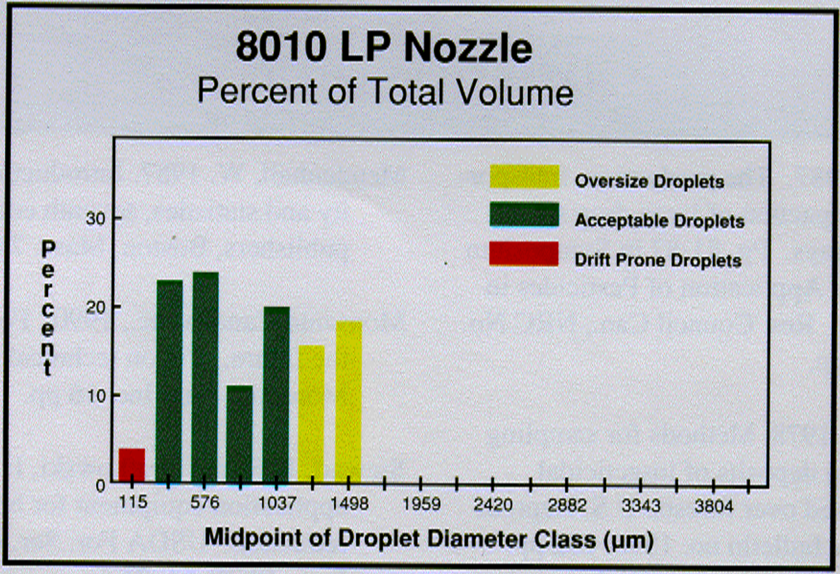

Figure 6. The distribution of spray volume by droplet diameter class emitted by the 8010 LP nozzle.

CONCLUSIONS

Five commonly used nozzle types were tested with water and dye in a simulated glyphosate application by helicopter. These tests showed that the droplet size distribution produced by these nozzles varied. This allows for flexibility in nozzle selection choosing between nozzle types to achieve a given combination of efficacy and drift control.

1) The D8-45 nozzle produced the highest percentage of volume in both the acceptable and the herbicide manufacturer's recommended range (85% and22% respectively). The nozzle also produced the highest percentage in the drift prone category (4%) making this assembly suitable where sites are not adjacent to sensitive areas.

2) Similar to the D8-45, the 8010 LP nozzle was found to contain 68% of the total volume in the acceptable range and 20% within the range recommended by the manufacturer. The 8010 had the narrowest drop size spectrum (46 to 1568 µm classes) and less volume in the most drift prone size class (<92 µm) than the D8-45. The 8010 assembly is suitable where conventional buffers are utilized.
3) The D8-46 nozzle contained 48% of the volume in the acceptable and 8% in the manufacturer's range. Over half the volume was in the larger size category with only 1% in the drift prone range. Droplets were sporadic and few in number in the classes greater than 1844 µm, making this nozzle suitable where a small reduction in efficacy can be tolerated and greater drift control is required.
4) The D6 JET and D8 JET produced the least amount of volume in the acceptable range (18% and 20% respectively) as well as in the drift prone category (0.4% and 0.3% respectively). Both nozzles produced a wide spectrum of droplets, with a considerable percentage in excess of 2500 µm. These nozzles could be used where considerable efficacy reduction can be tolerated for better control of drift but are not recommended for general use.

The results of this study are specific to the helicopter and spray system used. Alternate equipment or adjustments could result in different drop size distributions.

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APPENDIX I

THE FLOW RATE, APPLICATION RATE, BOOM PRESSURE AND WEATHER FOR EACH PASS

Nozzle	Pass	Flow Rate (1/min)	Application Rate (1/ha)	Boom Pressure (P.S.I.)	Temperature (°C)	Wind Speed (km/hr)	Relative Humidity (%)
D6 JET	1	168	46	28	10.5	0	85
	2	130	35	16	10.5	0	78
D8 JET	1	188	51	18	11.0	1	78
	2	130	35	10	10.5	0	78
D8-45	1	144	39	32	10.0	2	73
	2	130	35	26	7.0	1	97
D8-46	1	168	46	12	7.5	0	95
	2	152	41	11	8.5	0	82
8010-LP	1	177	45	14	ND	5	96
	2	177	45	14	ND	5	96

l/min = litres per minute
l/ha = litres per hectare
P.S.I. = pounds per square inch
km/hr = kilometers per hour
ND = no data

APPENDIX II

PERCENT OF DROPLET VOLUME FOR EACH NOZZLE BY DIAMETER CLASS

Droplet Size Range Classification	Midpoint of Diameter Class	Upper Diameter Limit	Jet or Nozzle Type				
			D6 Jet	D8 Jet	D8 45	D8 46	8010
Drift Prone (≤231 µm)	115	46	0	0	0.02	0	0.01
		92	0.01	0.01	0.21	0.05	0.08
		138	0.04	0.04	0.68	0.20	0.40
		184	0.10	0.07	1.14	0.37	0.86
		231	0.26	0.17	2.17	0.58	1.64
Acceptable (>231 to≤1153 µm)							
Manufacturer's Recommended (>231 to≤461 µm)	345	277	0.45	0.25	2.16	0.89	2.57
		323	0.68	0.43	3.33	1.69	4.23
		369	0.54	0.39	4.25	1.55	5.34
		415	0.77	0.51	3.36	1.58	3.64
		461	1.17	1.05	9.07	2.26	3.97
	576	507	0.92	0.69	9.82	2.92	5.48
		553	0.97	0.92	8.22	2.48	4.32
		599	0.83	0.66	4.16	2.32	4.84
		646	1.35	0.68	5.46	1.85	2.02
		692	0.85	1.06	7.53	2.67	3.97
	806	738	0.93	1.06	5.76	3.48	2.41
		784	0.52	1.41	2.86	2.74	1.44
		830	0.34	0.88	2.83	3.42	2.57
		876	0.40	0.75	1.00	2.21	1.01
		922	0.85	2.32	4.27	1.88	2.35
	1037	968	1.16	0.63	4.49	1.90	6.81
		1014	1.44	0.87	1.55	4.06	1.56
		1061	0.70	1.50	1.77	1.78	8.94
		1107	1.07	1.51	1.34	4.05	0
		1153	1.96	2.56	1.52	2.75	0
Over Size (>1153 µm)	1268	1199	1.02	0.96	1.71	2.06	0
		1245	0.95	1.35	0	1.15	2.89
		1291	0.63	1.20	0	1.29	3.23
		1337	0.71	1.33	0	0	3.58
		1383	2.86	3.32	2.62	3.16	3.97
	1498	1429	1.15	1.22	1.45	2.62	0
		1476	0.95	2.69	3.18	1.92	4.82
		1522	0.69	1.97	0	6.32	5.28
		1568	1.14	2.15	0	0	5.78
		1614	1.65	2.35	2.08	0	0
	1729	1660	1.80	1.28	0	2.73	0
		1706	0.98	1.39	0	1.48	0
		1752	0.53	1.50	0	3.22	0
		1798	0	1.62	0	1.74	0
		1844	3.70	1.75	0	3.75	0
	1959	1891	1.33	1.89	0	0	0
		1937	1.43	3.04	0	0	0
		1983	0.77	5.44	0	2.33	0
		2029	1.64	0	0	4.99	0
		2075	0.88	2.49	0	0	0
	2190	2121	0.94	2.66	0	0	0
		2167	3.00	4.26	0	3.04	0
		2213	1.07	1.51	0	0	0
		2259	1.13	0	0	0	0
		2306	1.21	3.42	0	3.66	0
	2420	2352	0	3.63	0	0	0
		2398	0	1.92	0	0	0
		2444	0	2.04	0	0	0
		2490	0	2.15	0	0	0
		2536	1.60	2.28	0	4.87	0
	2651	2582	3.39	2.40	0	0	0
		2628	0	2.53	0	0	0
		2674	1.88	0	0	0	0
	2882	2859	0	6.52	0	0	0
		2997	2.65	0	0	0	0
	3112	3228	3.31	0	0	0	0
	3343	3274	3.45	0	0	0	0
		3320	0	5.10	0	0	0
		3458	8.14	0	0	0	0
	3573	3689	4.94	0	0	0	0
	4034	3966	6.13	0	0	0	0
		4150	14.06	0	0	0	0

Monsanto® recommends a range of 250 - 500 µm. Since the class limits did not correspond, the manufacturer's range was adjusted to >231 - ≤461 µm.

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